PHYSICS 20

Module 2

Explaining Why Things Move

Distance Learning

Alberta EDUCATION

Physics 20

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Explaining Why Things Move

Alberta
EDUCATION

Distance Learning

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Administrators	
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General Public	
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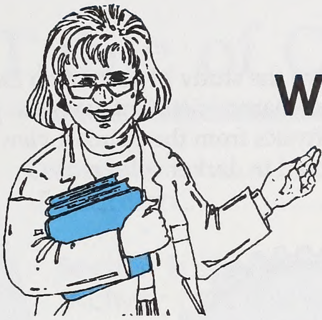
Physics 20
Student Module
Module 2
Explaining Why Things Move
Alberta Distance Learning Centre
ISBN No. 0-7741-0828-2

Cover Photo: WESTFILE INC.



Welcome to Module 2!

We hope you'll enjoy your study of *Explaining Why Things Move.*

To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.

You also have the option of viewing laser videodisc clips when you see the bar codes like this one.

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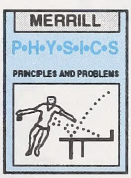
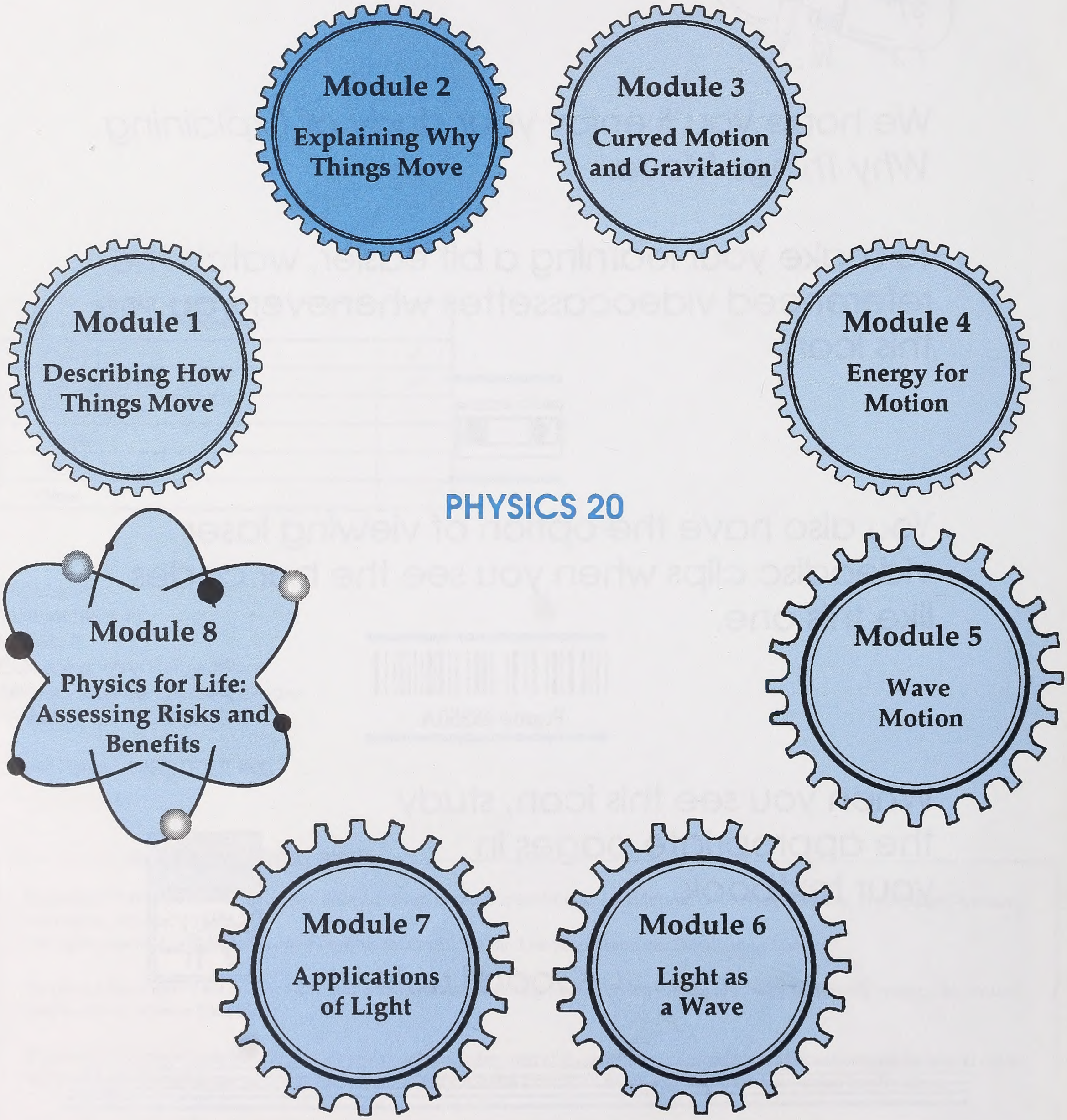
When you see this icon, study the appropriate pages in your textbook.



Good Luck!

Course Overview

This course contains eight modules. The first four modules involve the study of motion on Earth and in the heavens. Modules 5, 6, and 7 investigate the properties and characteristics of waves in general and light waves. The last module is an introduction to nuclear physics from the point of view of risk/benefit analysis. The module you are working in is highlighted in darker colour.



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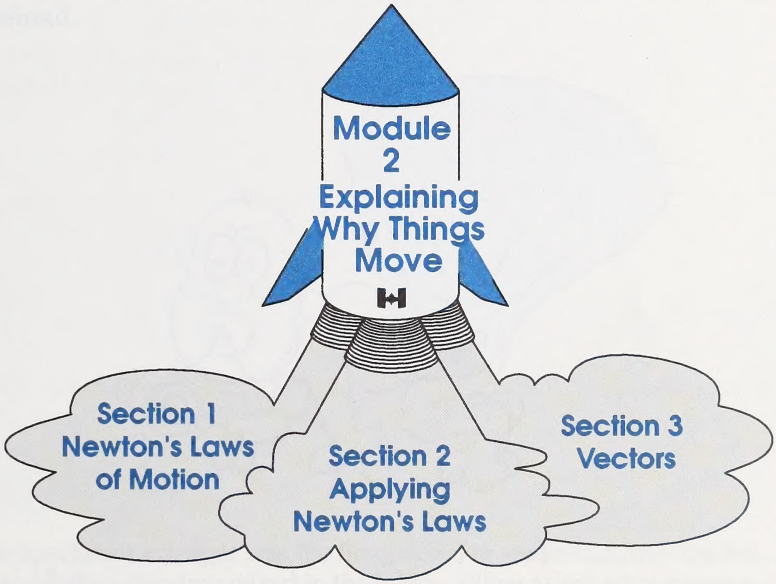
OVERVIEW

Have you ever wondered why distance runners need to wear special shoes or why hang gliders can stay in the air for so long?

Module 2 will explain why objects move the way they do. Newton's three laws will form the basis for these explanations. Newton's laws explain how forces affect motion. You will be studying these laws through the use of mathematics. Other related topics in this module include the force of friction, momentum, and vectors.



Evaluation

Your mark in this module will be determined by your work in the Assignment Booklet. You must complete all assignments. In this module you are expected to complete three section assignments. The mark distribution is as follows:

Section 1 Assignment	36 marks
Section 2 Assignment	27 marks
Section 3 Assignment	37 marks
TOTAL	**100 marks**

Section

1 Newton's Laws of Motion

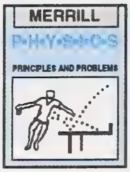
Imagine that you live in an apartment nine storeys above the ground. You accidentally lean against the window, push out the screen, and fall right out! This actually happened to two-year old Joshua Beatty from Detroit. Joshua miraculously walked away from this 27-m fall with only a scratch on his forehead.

The apartment manager was the first person to see Joshua after the fall. He found Joshua standing naked in the lobby. When asked what happened, Joshua replied, "I fell."

What saved Joshua? The answer must have something to do with the diaper and sock found hanging in the bushes outside the apartment building. You will look at the mathematics of this explanation later.

In this section you will learn about Newton's first law of motion. You will analyse data from a ticker tape experiment and use this data to help develop Newton's second law of motion. Finally, you will see how the third law of motion relates to the other two laws and to the concepts of mass, weight, and friction.

Activity 1: Forces and Newton's First Law



Joshua Beatty was very lucky. He knew very little about forces, yet he survived a tremendous fall. You can begin to learn about forces by reading pages 87 and 88 of your textbook.

1. What is the difference between kinematics and dynamics?

2. What is a force?

When you think about forces, do you ever think about any of the following things? They are all actually very common examples of forces.

- magnetic effects
- falling water
- the collision between a baseball and a bat
- the moon's effect on the tides
- the collapse of a star
- blowing wind
- proton-proton repulsion

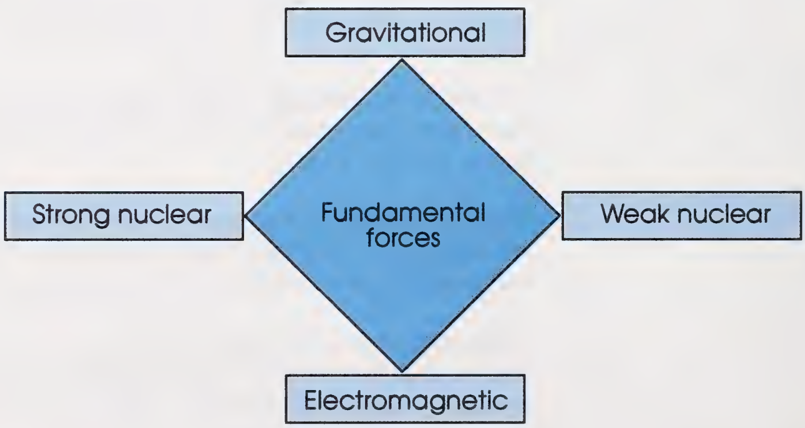
Although there are many examples of forces, they are classified into only four fundamental types.

gravitational force – an attractive force that exists between all objects due to their mass

electromagnetic force – an attractive or repulsive force that exists between charged objects

strong nuclear force – holds the particles of the nucleus together

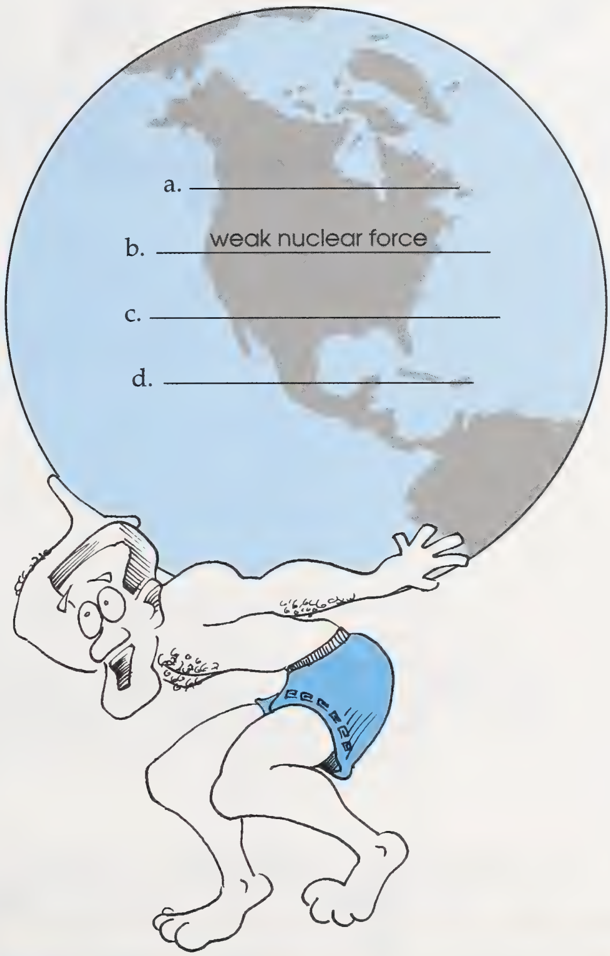
weak nuclear force – governs radioactive decay



3. Which of the fundamental forces is responsible for ocean tides?

4. Which of the fundamental forces exert their influence over extremely short distances?

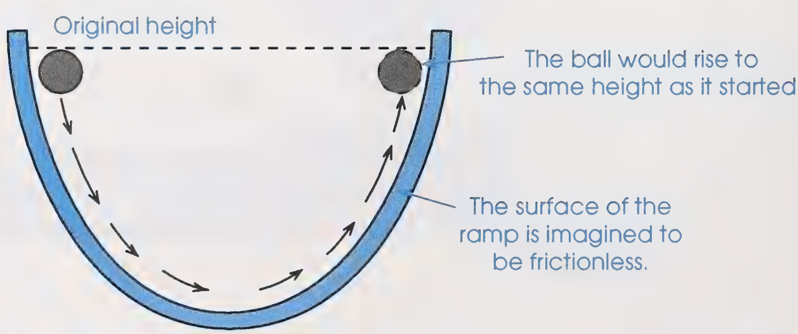
5. On the following chart list the four fundamental forces in order of their relative strengths.



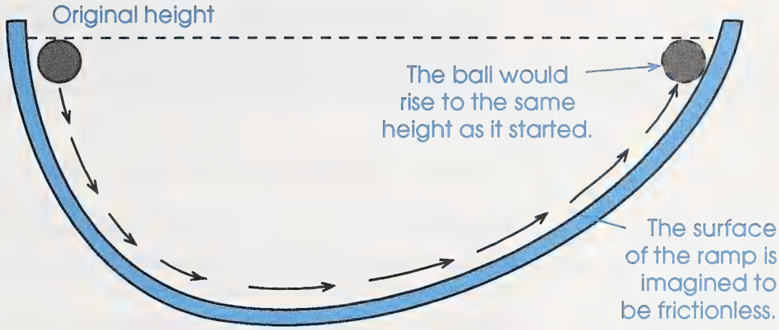
Check your answers by turning to the Appendix, Section 1: Activity 1.

Now imagine yourself skiing down a hill.

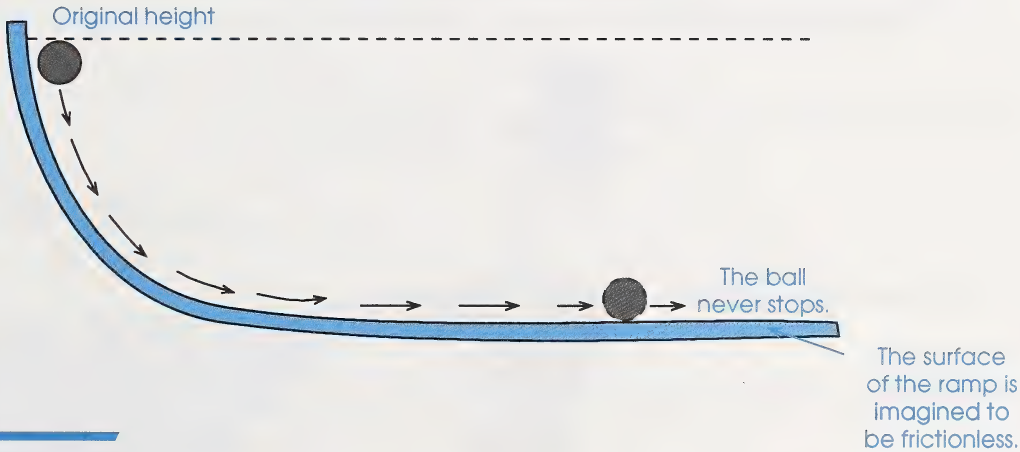
Once you arrive at the bottom of the hill, you slowly come to a stop. What stops you? The ancient Greeks had an explanation. They thought that you had reached your natural place at the bottom, and so it was normal to stop. Galileo had a different idea. He devised a thought experiment in which he imagined that he rolled a ball down a ramp. He suggested that if all frictional forces could be removed, the ball would rise to the same height from which it started.



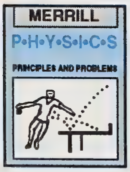
Galileo then reasoned that if the ramp was lengthened, the ball would still rise to its original height.



According to this thought experiment, if all the friction was removed, the ball would roll back and forth forever, always rising to its original height. But what if one end of the ramp was made flat? Galileo thought that the ball would continue rolling forever!



Newton's first law – If no external net forces act on an object, the object will maintain its velocity.



A little more than 300 years ago, Isaac Newton extended Galileo's thought experiment into what is now called **Newton's first law**. This law states that an object at rest tends to stay at rest unless acted on by some unbalanced force, and an object in motion tends to stay in motion unless acted on by some unbalanced force. To discover more about Newton's first law, read page 89 of your textbook.

6. Does Newton's first law agree with the Greeks' explanation of motion or with Galileo's explanation?

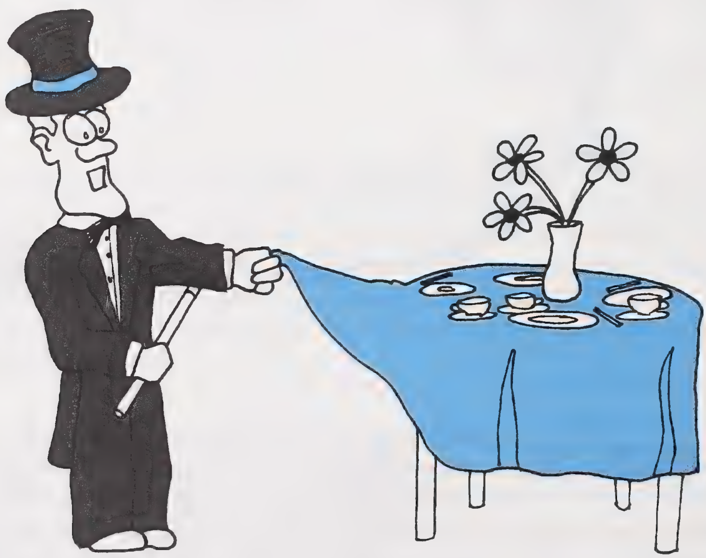
Check your answers by turning to the Appendix, Section 1: Activity 1.

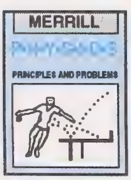
Newton's explanation of motion holds true both on Earth and out in space.

Imagine being on board a space mission to the moon. Your rockets have lifted you above Earth's strong gravitational pull and blasted you off towards the moon. You have reached a speed of 10 km/s, but you no longer need the rockets to maintain this speed because you're whizzing along through frictionless space.

Experiencing Newton's First Law of Motion

Have you ever seen a magician pull a tablecloth out from under dishes set on a table?





Although it may seem miraculous, it's actually just a demonstration of Newton's first law of motion. You can try a similar trick by doing the demonstration shown on the bottom of page 90 in your textbook.

Investigation: Demonstrating Newton's First Law of Motion

Science Skills

- [ ] A. Initiating
- [ ] B. Collecting
- [ ] C. Organizing
- [x] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

Purpose

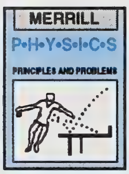
In this investigation you will perform a simple trick to show how Newton's first law applies to a penny.

Materials

You will need the following materials for this investigation:

- a smooth piece of cardboard (an index card or a playing card)
- a penny
- a glass

Procedure



- Set up the materials as shown in Figure 5-4a on page 90 of your textbook.
- Quickly flick the card out from under the penny. If necessary, modify your technique until the trick works.

Analysis

7. Explain why the penny stayed in place instead of moving horizontally with the card.

8. Use Newton's first law to explain why it was important to have a smooth card. You can test this idea by taping a small piece of sandpaper to the card and repeating the demonstration.

9. Use your previous answers to explain the magician's trick with the tablecloth.

Applying Newton's First Law of Motion

Newton's first law of motion can explain more than just a magician's trick. To see how this law can be applied to automobile safety, do the following questions.

10. Do Applying Concepts question 2 on page 105 of your textbook. Use diagrams to show how this situation is different from the penny trick.

11. Imagine that you are travelling down the road in a car at 60 km/h when you hit a large tree. Use Newton's first law to explain how a seatbelt could save your life.

In the next activity you will investigate Newton's second law of motion.

Check your answers by turning to the Appendix, Section 1: Activity 1.

Activity 2: Investigating Acceleration

Have you ever been amazed by how fast a snowmobile can accelerate?

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What do you think would happen if the same snowmobile had two riders instead of just one? Would the rate of acceleration be the same?

This activity will help you to answer these questions by exploring the relationships between net force, acceleration, and the mass of the accelerating object.

Investigation: Mass and Acceleration

Science Skills

- ❑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ❑ F. Evaluating

Purpose

In this investigation you will analyse the relationship between the mass and acceleration of an object when a net force is applied.

PATHWAYS

If you have access to laboratory facilities and the materials listed for Part A, do Part A. If you do not have access to these things, do Part B.

Part A

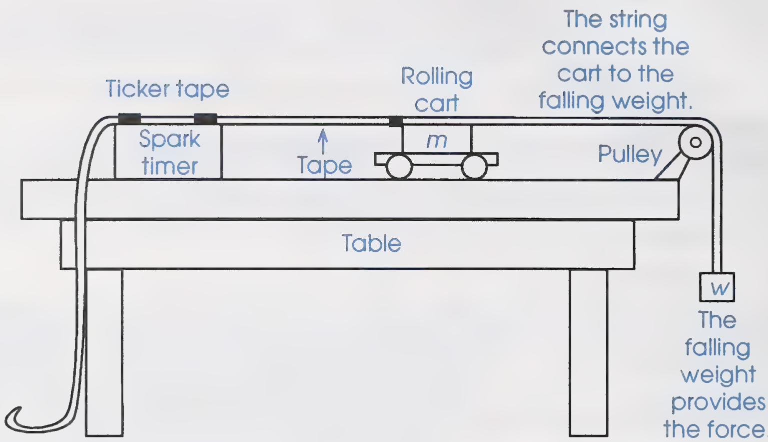
Materials

You will need the following materials for this investigation:

- spark timer
- ticker tape
- a long table that is about 1 m tall
- rolling cart
- scale
- various masses
- tape
- string
- pulley
- a metre stick or clear plastic ruler

Procedure

- Assemble the materials as shown in the following diagram.



- Set the spark timer for 10 sparks per second.
- Let the weight fall and pull the ticker tape through the timer. There will be holes burned into the tape every 0.10 s.
- Circle the marks on the ticker tape and number them 0 to 20.
- Repeat the procedure using the same falling weight, but double the mass of the system by adding mass on top of the rolling cart. **The added mass should equal the sum of the mass of the cart and the mass of the falling weight.**
- Collect the data with a metre stick and complete the investigation as described under the headings Data and Analysis.

Data

1. To help you organize the data, you have been provided with Table 1. Fill in the Position column by measuring the distance between each spark and the spark labelled 0.

Table for Ticker Tape Data – Part A

TABLE 1				TABLE 2			
Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)	Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)
0				0			
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			
11				11			
12				12			
13				13			
14				14			
15				15			
16				16			
17				17			
18				18			
19				19			
20				20			

To complete the rest of the investigation, skip ahead to the Analysis section following Part B.

End of Part A

Part B

Materials

You will need the following materials for this investigation:

- scissors
- transparent tape

Procedure

- You have been provided with sample data for the procedure outlined in Part A. Carefully read the procedure from Part A so that you understand how the ticker tape was prepared.

- You will find the ticker tapes for this experiment at the end of the Appendix. The tape representing the mass of the system being doubled is grey. You will not be using the grey tape until the Analysis section of this investigation. Carefully cut out these tapes and arrange them end to end in alphabetical order. You may need to tape the strips down so that they do not move.

- Collect the data with the cut-out ruler that is included with the strips and complete the investigation as described under the headings Data and Analysis.

Data

2. To help you analyse the data, you have been provided with Table 1 which has been partially completed to help you get started. Fill in the Position column by measuring the distance between each spark and the spark labelled 0.

End of Part B

Table for Ticker Tape Data – Part B							
TABLE 1				TABLE 2			
Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)	Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)
0	0	–	–	0	0	–	–
1	0.6	0.6	6.0	1	0.6	0.6	6.0
2	1.5	0.9	9.0	2	1.4	0.8	8.0
3	3.1	1.6	16	3	2.6		
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			
11				11			
12				12			
13				13			
14				14			
15				15			
16				16			
17				17			
18				18			
19				19			
20				20			

Analysis

3. The Displacement from Previous Dot column represents the displacement between each spark. It can be obtained by subtracting the successive values in the first column you measured. Record your answers on Table 1.

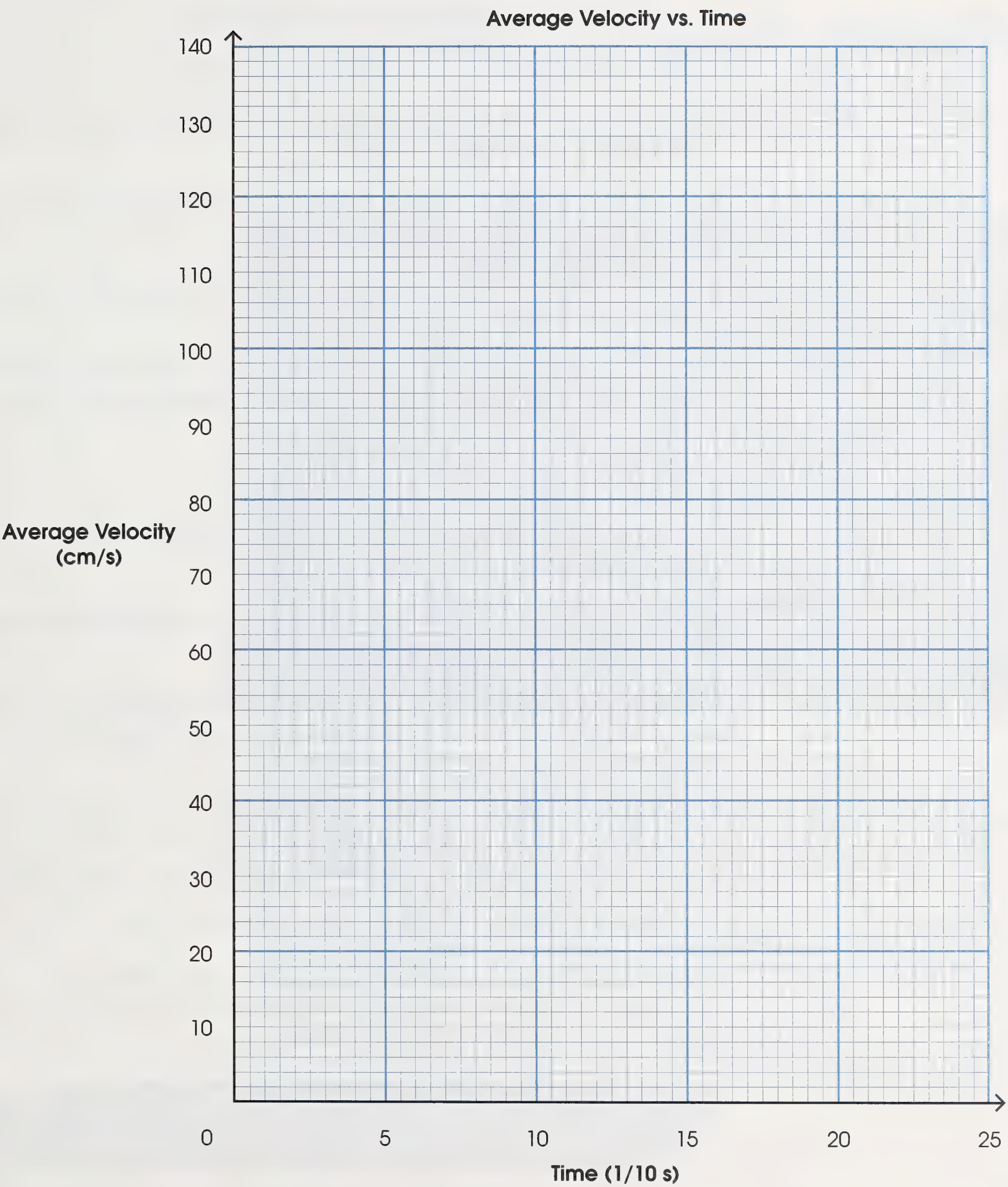
4. The Average Velocity in the Interval column can be easily calculated using the following equation.

$$\text{average velocity} = \frac{\text{displacement}}{\text{interval time}}$$

   The displacement in the equation is the displacement from the previous dot and the total time is the same for each interval. If the spark timer is operating at 10 sparks per second, the time between each spark is 1/10 s. Dividing by 1/10 s is like multiplying by 10! Record your answers in Table 1.

5. When you have completed Table 1, repeat the whole procedure for the grey tape. The grey tape was obtained by doubling the mass on the cart and keeping the accelerating weight the same. Record the data in Table 2. When both Table 1 and Table 2 are completed, you will be ready to graph the results.

6. For each table, plot the average velocity against the time when the average velocity occurred. Remember from Module 1 that the average velocity occurs in the middle of the time interval. Plot both tables on the same graph. Circle your experimental points and draw best fit lines. Calculate the slopes of the best fit lines right on the graph paper. Show all your work!


Average Velocity vs. Time
Average Velocity (cm/s)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
Time (1/10 s)

7. What are the units of the slope of the best fit line?

8. What do the slopes of the best fit lines represent?

9. What was the effect of doubling the mass of this system while keeping the force on the system constant?

10. How long would the intervals be if the spark timer was set to 20 sparks per second?

11. What would be the effect of tripling the mass while keeping the force constant?

12. If you would have plotted the Position column from Table 1 against time, what kind of best fit line do you think you would have obtained?

Conclusion

13. In mathematical terms, what is the relationship between mass and acceleration?

14. What is the relationship between the number of sparks per second and the time between sparks?

At the beginning of this activity you were asked to compare the motion of two snowmobiles. Use what you learned from this investigation to reconsider your earlier thoughts about the snowmobiles.

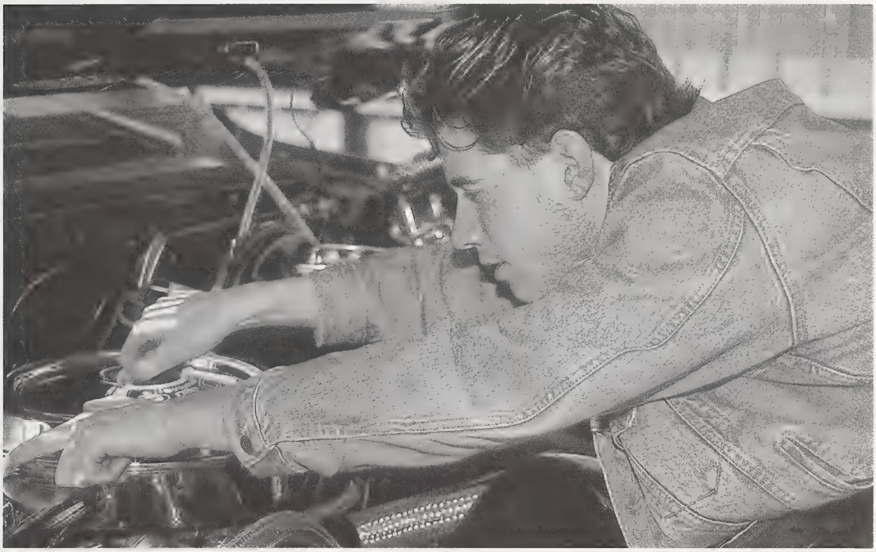
15. Imagine that two snowmobiles are identical in every respect except for the riders. One machine has a single rider with a small mass and the other machine has two riders with a large combined mass. If the same net force acts on each machine, how would the motion of one machine compare to the other if both machines started from rest?

In this activity you have seen how the mass of an object affects its acceleration. In the next activity you will see how the force that is exerted on an object influences the resulting acceleration.

Check your answers by turning to the Appendix, Section 1: Activity 2.

Activity 3: Newton's Second Law

If you and a friend owned exactly the same kind of cars, but you had your engine replaced with one that delivered twice the horsepower, your car would obviously be much faster than your friend's car.



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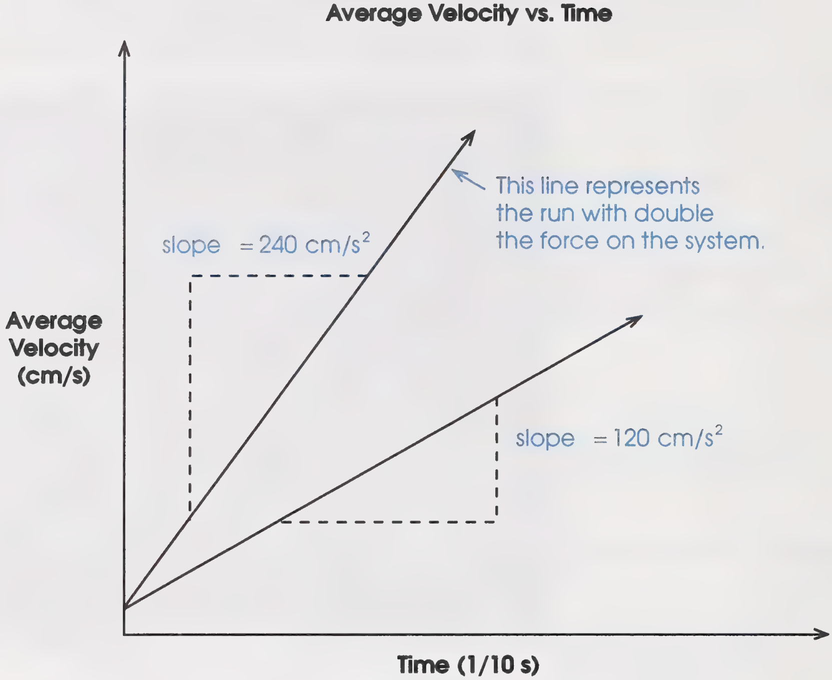
If you have access to a spark timer, you might try to investigate the relationship between force and acceleration. Can you think of a way to do this? One method would be to use a cart and a hanging weight as you did in Activity 2. This time keep the mass of the system constant and double the mass of the hanging weight. This will double the force on the system.

1. Predict how the acceleration of the cart will change if the force on the system is doubled.

The experiment described on the previous page was done for you. The ticker tape was analysed and tables were completed. The average velocity between sparks was plotted against time. The following graph shows the results.



If the force on the system is tripled, the acceleration will triple. If the force on the system is reduced to one quarter, the acceleration will be reduced to one quarter.

2. What mathematical relationship exists between force and acceleration?

manipulated variable – the variable that is altered

The variable which is altered in the experiment is called the **manipulated variable**. The variable which is affected by this change is called the **responding variable**.

responding variable – the variable that is affected by the change in the manipulated variable

3. In the experiment just described, which are the manipulated and responding variables?

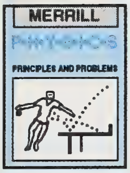
Check your answers by turning to the Appendix, Section 1: Activity 3.

Newton's second law – $\vec{F}_{net} = m\vec{a}$

You have seen how force and mass affect the acceleration of an object. This relationship is described by **Newton's second law**. This law states that the acceleration of a body is directly proportional to the net force acting on it and inversely proportional to its mass. This can be summarized simply by $\vec{F}_{net} = m\vec{a}$.

4. What is the standard unit of mass in SI metric units?

5. What is the standard unit of acceleration in SI metric units?

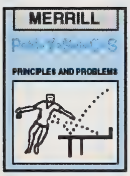


Turn to the top of page 91 of your textbook to discover the unit of force in SI metric units.

6. What is the name of the unit of force in SI metric units?

7. How is the unit of force defined?

Check your answers by turning to the Appendix, Section 1: Activity 3.



Now that you know a unit for force and an equation for Newton's second law, you can learn how this law can be applied. Study the Example Problems on page 91. In the case of the second example, you would be expected to use $v_f^{\,2} = v_i^{\,2} + 2ad$ instead of the vector version presented in the example.

8. Do Practice Problems 1, 2, 3, and 4 on page 92 of your textbook. Be sure to use vector notation in a way that is consistent with the techniques from Module 1.

Check your answers by turning to page 662 in your textbook.

You have seen how Newton's second law describes the motion of an object when a net force acts on it. Earlier in the module you learned that Newton's first law describes the motion on an object when no net force acts on it. In the next activity you will examine Newton's third law of motion.

Activity 4: Newton's Third Law and Friction

Newton's third law – For every action there is an equal and opposite reaction.

Have you ever wondered how a bird can fly or how a rocket can send a man to the moon? Both of these can be explained by **Newton's third law of motion**. This law states that for every action there is an equal and opposite reaction. Thus, rocket propulsion can be explained by equating the force of the exhaust particles with the equal and opposite force on the rocket body. A bird flapping its wings down on the air can receive an opposite push upward from the air. This is how birds are lifted into flight.

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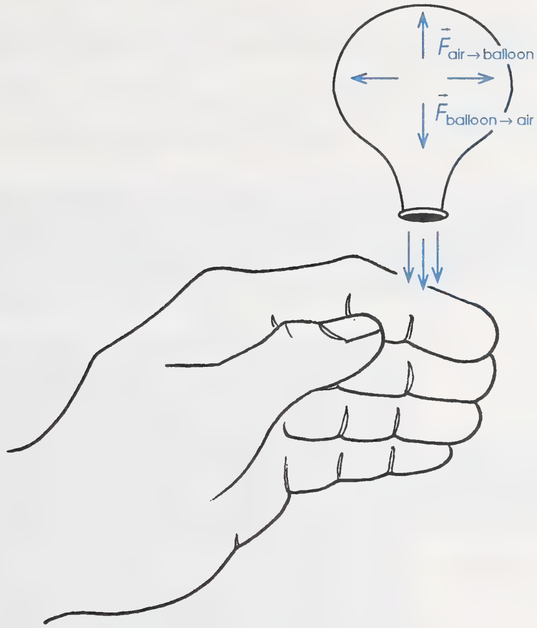
Imagine holding a blown-up balloon in your hand and then releasing it.



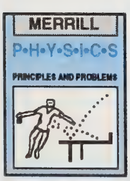
The reason why it moves is very similar to why a rocket moves. The air pressure in the balloon pushes outward in all directions. The left-right forces would cancel each other and, because of the hole in the bottom, the upward force on the inside of the balloon is greater than the downward force. This imbalance causes the balloon to move upward! Another way to think about this is to describe the balloon in terms of two forces: the force of the balloon on the air (the **action** force) and the force of the air on the balloon (**reaction** force). These two forces are called an action-reaction pair.

Newton's third law could be written as follows.

$$\boxed{\vec{F}_{balloon \rightarrow air} = -\vec{F}_{air \rightarrow balloon}}$$

The sizes of the forces are equal, but they act on different objects and in opposite directions.

This same reasoning applies to any forces in an action-reaction pair. To see how this applies to a bowling ball, read from the middle of page 92 to the middle of page 93 in your textbook.



1. On page 92 of your textbook, Figure 5-6 shows the action-reaction pair between your hand and the ball and the action-reaction pair between Earth and the ball. Summarize these forces by writing an equation like the one that was given for the balloon in the previous example.

2. There is a pattern in the equations for action-reaction forces that is very helpful for remembering Newton's third law. What is the pattern?

The pattern that is so evident in Newton's third law can also be illustrated in the various ways that you move from one place to another. In the examples that follow, note that the action force is the force that you exert and the reaction force is the force that makes you move.

Action-Reaction Pair		
Activity	**Action Force**	**Reaction Force**
walking	$\vec{F}_{you \rightarrow ground}$	$-\vec{F}_{ground \rightarrow you}$
swimming	$\vec{F}_{you \rightarrow water}$	$-\vec{F}_{water \rightarrow you}$
canoeing	$\vec{F}_{paddle \rightarrow water}$	$-\vec{F}_{water \rightarrow paddle}$

In each activity you must exert a backwards action force in order to be supplied with a reaction force to move forwards.

Although these activities demonstrate Newton's third law, examples which illustrate all of Newton's laws can be found in everyday life.

3. List which of Newton's laws is responsible for each of the following phenomena and explain why.

   a. rocket propulsion

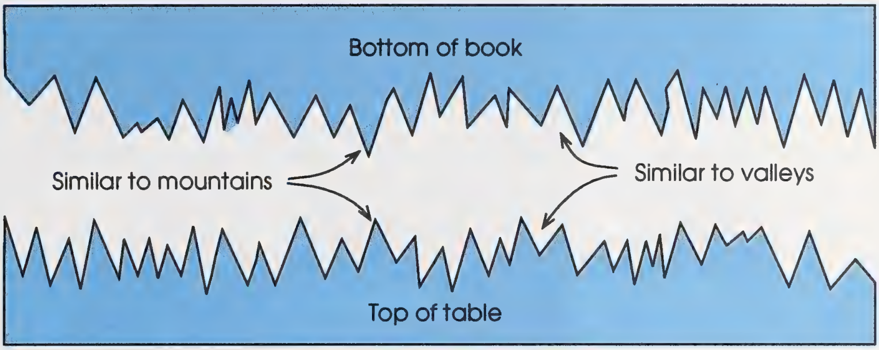
   b. whiplash

4. At trackmeets, shotputters generally have large frames, whereas sprinters are usually light. Use Newton's laws to explain why.

Friction

friction – the force that opposes the motion between two surfaces

You have heard friction mentioned often in the discussion of forces. Give your physics book a push as it rests on the table. It doesn't slide very far before returning to rest, does it? But what stopped it? If you could magnify the bottom of the book and the top of the table, you would see that they are not as smooth as you might think.



As the book and the table are pressed together, the "mountains" and "valleys" become intertwined.

5. Why would two pieces of sandpaper have a greater frictional force between them than your book and the table?

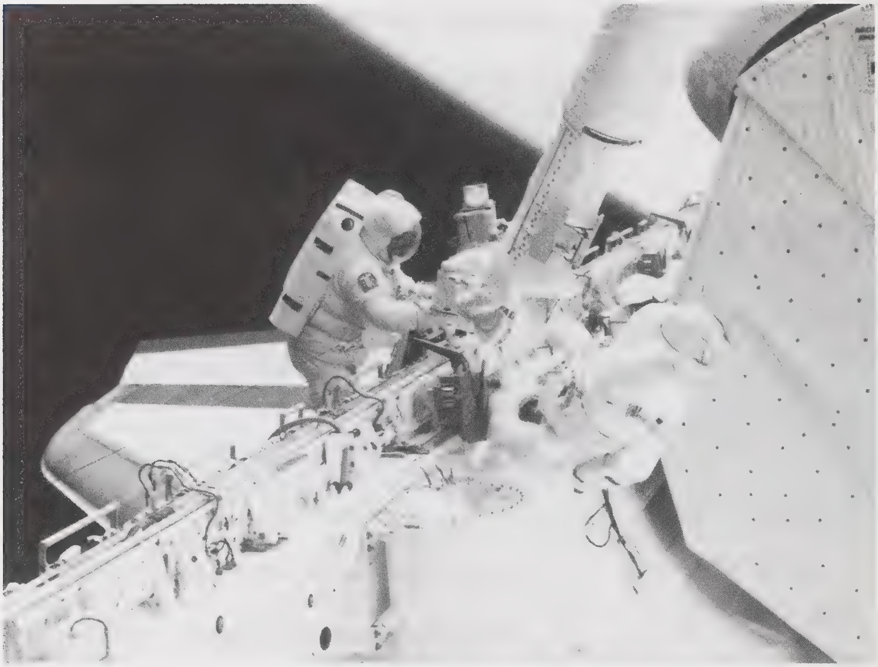
6. How does the force between the surfaces affect friction?

Inertia

Before learning about the meaning of inertia, attempt the following question.

7. Imagine that you have run out of gas and you have to push your car to the gas station. Why does it take more force (about three people) to get the car rolling, but less force (only one person) to keep it going?

Imagine that you are in the space shuttle orbiting around Earth. You and everything else are weightless. There are two similar packages floating in front of you. One contains popcorn and the other contains a small television. How is it possible to distinguish between the two packages without opening them?



NASA

mass – a measure of the quantity of matter a body contains

volume – the three-dimensional space which is occupied by an object

inertia – the tendency of an object not to change its motion

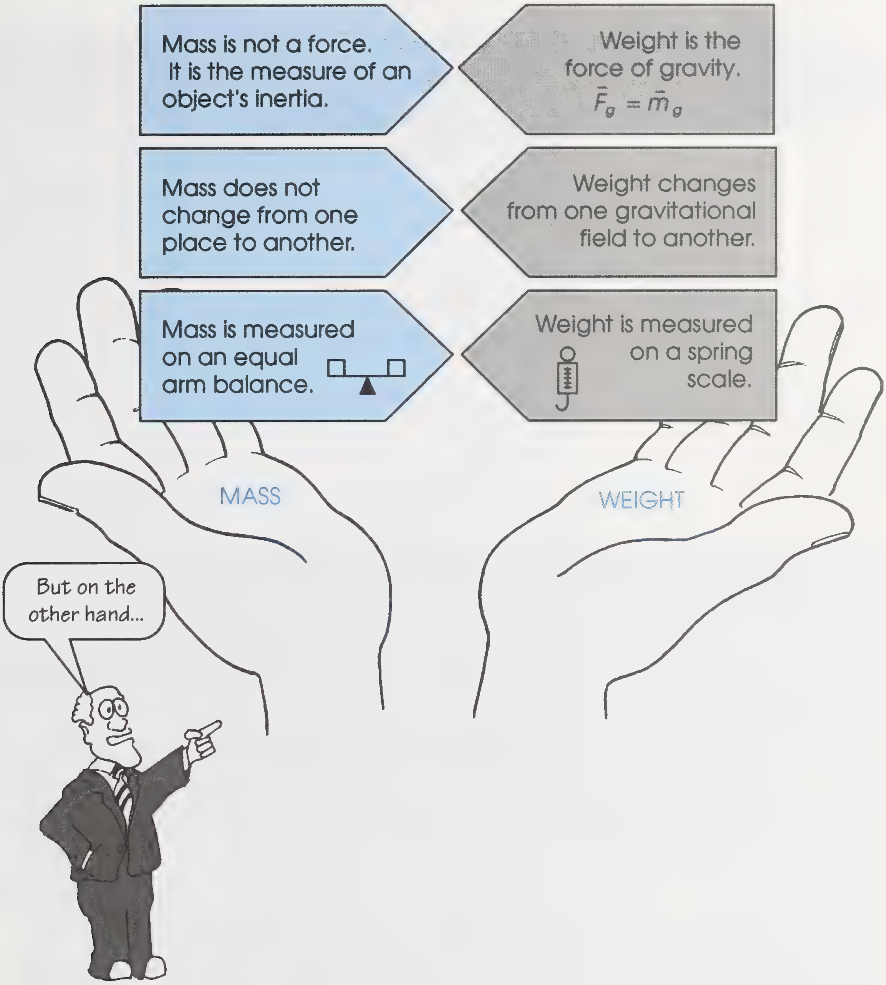
Because the television is made of denser material, it has a greater **mass** than the popcorn of equal **volume**. Because the television has a greater mass than the popcorn, it has a greater **inertia**. A greater inertia means it has a greater tendency to remain at rest once at rest and a greater tendency to remain in motion once in motion.

8. Which of Newton's laws could also be called the law of inertia?

9. How would it be possible to distinguish between the two floating packages in the example?

Check your answers by turning to the Appendix, Section 1: Activity 4.

Although the television in orbit has mass, to an orbitting astronaut it appears to have no weight. This diagram compares weight to mass.



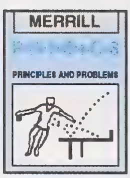
To remind you that weight is the force of gravity acting on an object, the symbol F_g will be used instead of W, which is used in your textbook. For additional discussion about mass and weight, read pages 94 to 96 of your textbook. When applying the ideas of mass and weight to problem solving, it is important to be consistent. Whether you regard weight as a vector or a scalar will depend on the nature of the question. Consider the following example.

Example

Find the weight of a 55-kg barbell.

Comparison of Two Possible Solutions	
Scalar Approach	**Vector Approach**
$m = 55\ \text{kg}$ $g = 9.80\ \text{m/s}^2$ $F_g = ?$	$m = 55\ \text{kg}$ $\vec{g} = -9.80\ \text{m/s}^2$ $\vec{F}_g = ?$
$F_g = mg$ $= (55\ \text{kg})(9.80\ \text{m/s}^2)$ $= 539\ \text{N}$ $= 5.4 \times 10^2\ \text{N}$	$\vec{F}_g = m\vec{g}$ $= (55\ \text{kg})(-9.80\ \text{m/s}^2)$ $= -539\ \text{N}$ $= -5.4 \times 10^2\ \text{N}$
The weight is 5.4×10^2 N.	The weight is 5.4×10^2 N down.
• No vector arrows are placed above the variables g and F_g. • No indication is given about the direction of the weight. • Only the size of the weight is given.	• Vector arrows are placed above the variables $\vec{g}$ and $\vec{F}_g$. • Direction is indicated by the negative sign and the word "down". • Both the size and the direction of the weight are given.

Which approach is best? If you use the vector solution, you are always safe. Even if direction isn't required, you can find it anyway. However, the scalar solution would be considered just as correct as the vector solution.



Don't mix the two methods. Unfortunately the Example Problem on page 94 of your textbook is not as consistent as it should be.

10. Use the vector approach to find inconsistencies in the Example Problem given on page 94 of your textbook. Rewrite the problem using a consistent vector approach.

11. To see how the ideas of mass and weight can be used, do Practice Problems 5, 6, 7, and 8 on page 94 of your textbook. Be consistent in the approach that you use for your solutions.

Check your answers by turning to the Appendix, Section 1: Activity 4.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Newton's laws can be summarized as shown.

<table>
<tr><th>Newton's First Law</th><th>Newton's Second Law</th></tr>
<tr><td>• There is no net force.
• Objects have a constant velocity ($\bar{v} = 0$) or uniform motion.
• In the absence of net forces, objects maintain their velocity.
• Also known as the law of inertia.</td><td>• There is a net force.
• Objects have a changing velocity (accelerated motion).
• A net force will cause an object to accelerate in the direction of that force, according to $\bar{F}_{net} = m\bar{a}$.</td></tr>
<tr><th colspan="2">Newton's Third Law</th></tr>
<tr><td colspan="2">Newton's third law says nothing about the type of motion an object will have. The third law simply states a relationship about forces.
• Forces always act in pairs.
• The forces in the pair are equal in size but opposite in direction.
• The forces act on different objects.
• For every action force, there is an equal but opposite reaction force, as given by $\bar{F}_{1\rightarrow 2} = -\bar{F}_{2\rightarrow 1}$.</td></tr>
</table>

1. Define the terms on the following chart. Illustrate the meaning of each term by correctly using it in a complete sentence.

Definitions		
Term	**Definition**	**The Term in a Complete Sentence**
Friction		
Inertia		
Mass		
Weight		
Force		

2. Use the comparison chart of Newton's Laws to determine whether the following situations are best explained by Newton's first, second, or third law. For each situation, write which of Newton's laws best applies and explain why.

   a. A car travels down a straight highway at a constant velocity.

   b. A paddle pushes against the water and causes the water to push back on the paddle.

   c. A bus driver suddenly hits the brakes. Passengers who were standing continue to move to the front of the bus and fall over each other.

   d. A driver increases speed to pass another car on the highway.

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Choose **one** of the following activities.

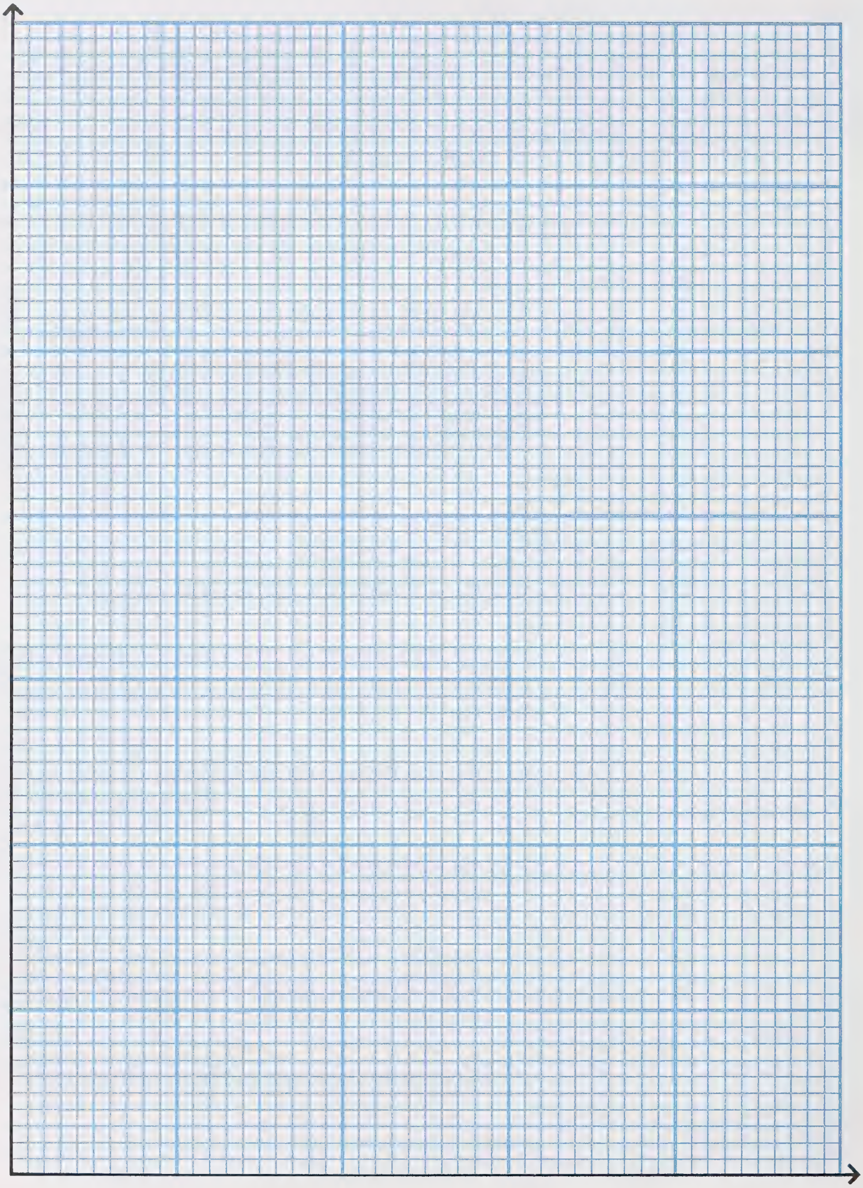
1. In Activity 2 you plotted a velocity versus time graph. Now you can plot position versus time. Use the data from Part B of the investigation in Activity 2.

   a. Plot the data from both Tables 1 and 2 on the same graph paper so you can compare them. Draw the best fit lines.

   b. Draw tangent lines at the fifteen tenths of a second mark and find the slopes of these lines on the graph paper.

   c. Compare the slopes of the tangent lines to the values in Tables 1 and 2 in the Average Speed in the Interval column for fifteen tenths of a second. They should be similar.

   d. What does the slope of the tangent line represent?



2. Visit your local public library and research the life of Isaac Newton.

   a. Find out some personal information about Isaac Newton. You must include the following items.

      - year of birth
      - year of death
      - marital status
      - number of children
      - country of residence
      - an interesting piece of trivia about him

   b. List Isaac Newton's accomplishments in the fields of mathematics and science.

3. If you can, work in a group and prepare three brief presentations in the form of TV commercials. Each commercial must explain one of Newton's three laws of motion. Each commercial should have a well-planned script that will allow you to get the main ideas across in less than 60 s. Be creative!

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

It is amazing how Newton's three laws are still useful for describing force and motion after 300 years. Newton's laws still work very well for everyday experiences, although it is now known that they need modification under extreme conditions, such as when objects approach the speed of light.

In the next section you will see how Newton's laws can be applied to solve a variety of problems.

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section

2 Applying Newton's Laws

WESTFILE INC.

The gymnast has nearly perfect control as her body performs very precise movements. It's natural to wonder how any human being could possibly learn how to do this.

Part of the answer lies in strength. The gymnast must be able to carefully control muscle groups so that the necessary force can be applied for a particular movement. In other words, explaining the motion of the gymnast requires analysis of forces and application of Newton's laws. The analysis would be quite complex.

In this section you will encounter a variety of problems relating to force and motion. You will learn about friction, net force, momentum, and impulse.

Activity 1: Friction

Before you start to mathematically apply Newton's laws to situations involving friction, it might be helpful to review the laws themselves.

PATHWAYS

If you have access to the video entitled *Force and Motion: Newton's Three Laws*, do Part A. If you do not have access to the video, do Part B.

Part A

The video *Force and Motion: Newton's Three Laws* uses a variety of demonstrations to illustrate the main ideas behind each law. Watch the video and then answer these questions.

1. Carefully describe Newton's three laws.

2. List three examples from the video that illustrate Newton's first law.

3. The video shows an experiment that collects data for Newton's second law. Summarize the results of this experiment by completing the following statements.

   a. As the force on an object increases, the acceleration tends to

      ______________.

   b. As the mass of an object increases, the acceleration tends to

      ______________.

4. How does the video define Newton's third law in terms of forces?

End of Part A

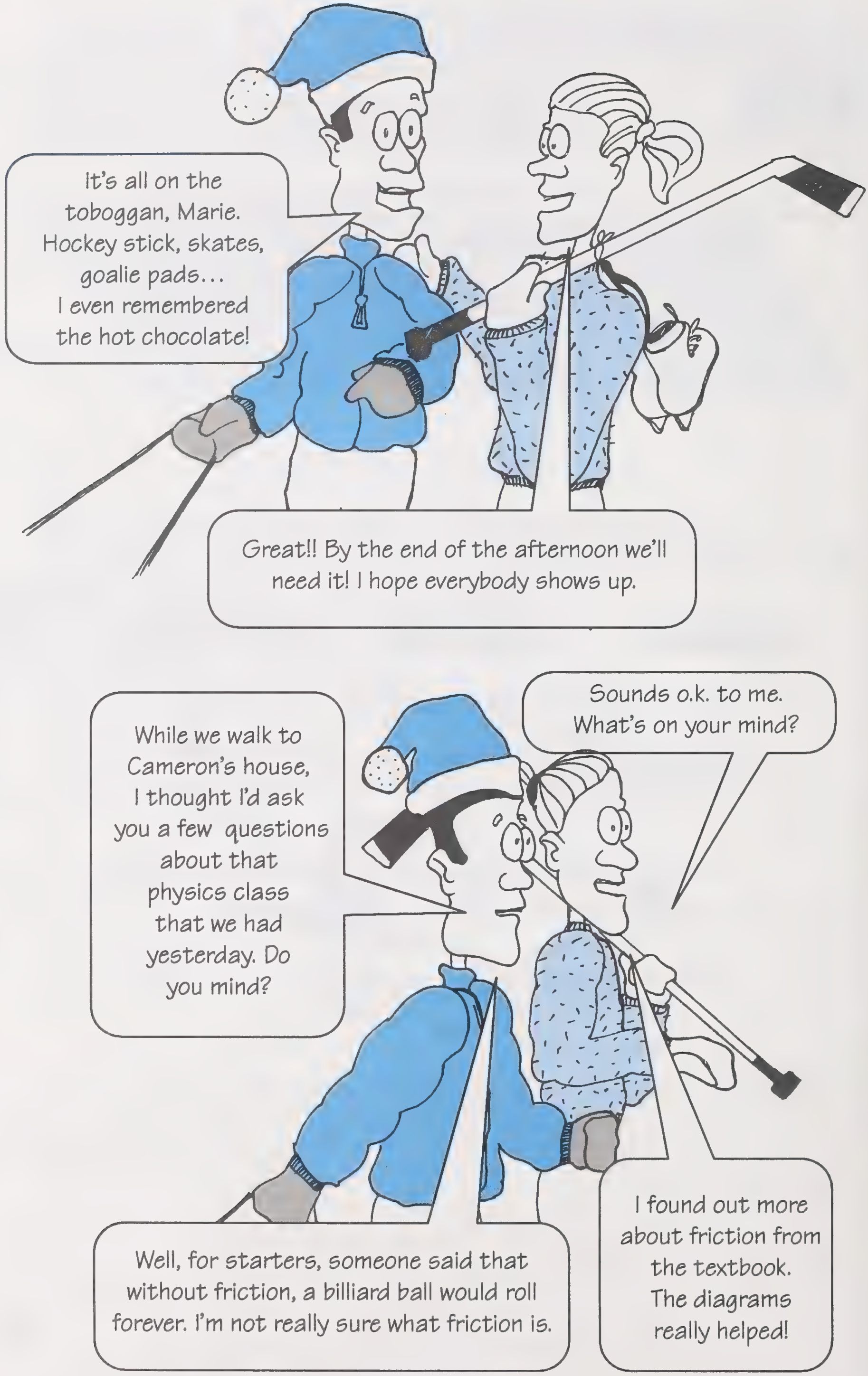
Part B

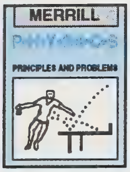
The main ideas of Newton's three laws of motion are summarized in the summary at the end of Chapter 5 in your textbook. Carefully read the summary of Section 5.1 on page 104 of your textbook.

5. Use the ideas in the summary and your understanding of Section 1 to solve Reviewing Concepts questions 3, 4, and 5 on page 104 of your textbook.

End of Part B

In the remainder of this section you will see how Newton's three laws can be applied to solve problems.


It's all on the toboggan, Marie. Hockey stick, skates, goalie pads… I even remembered the hot chocolate!
Great!! By the end of the afternoon we'll need it! I hope everybody shows up.
While we walk to Cameron's house, I thought I'd ask you a few questions about that physics class that we had yesterday. Do you mind?
Sounds o.k. to me. What's on your mind?
Well, for starters, someone said that without friction, a billiard ball would roll forever. I'm not really sure what friction is.
I found out more about friction from the textbook. The diagrams really helped!



Imagine that you are Marie and you are about to explain friction and the difference between static friction and sliding friction to Marc. Carefully read from the middle of page 96 to the end of the second paragraph on page 97 of your textbook.

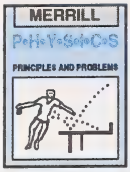
6. How would you explain to Marc that friction between his boots and the ground is necessary for him to be able to walk with the toboggan?

7. How would you explain why the toboggan has been designed to minimize friction?

8. How could you use the toboggan to demonstrate the differences between static friction and sliding friction?

9. Suppose Marc wanted to know how he could measure the size of the force of friction acting on the toboggan as he pulled it. Use Newton's first law to explain how this could be done.

Check your answers by turning to the Appendix, Section 2: Activity 1.

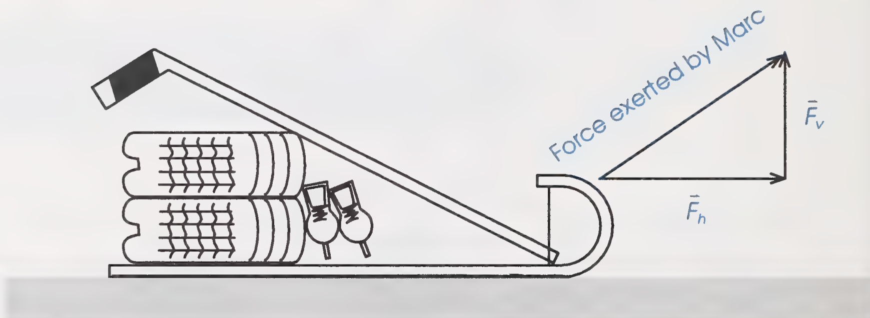


Note: Before reading any further in the textbook, it should be pointed out that there is an error in an equation in the textbook (see page 97). The equation should be written as follows:

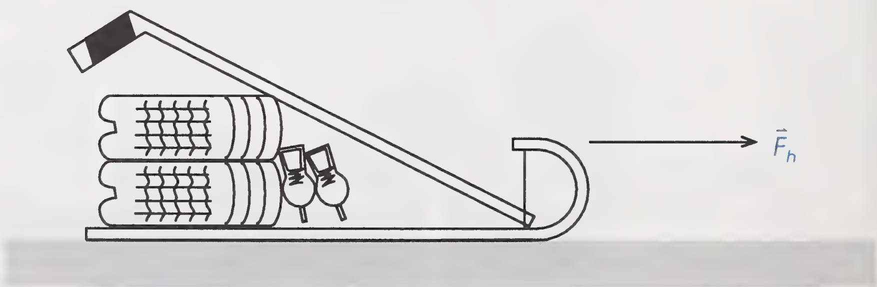
$$\boxed{F_f = \mu F_n}$$

The force of friction is written as F_f, not as F_i. The equation also should not be written as a vector equation. Since the force of friction and the normal force are perpendicular to each other, directions should not be included in this equation. Keep these things in mind as you read the rest of page 97.

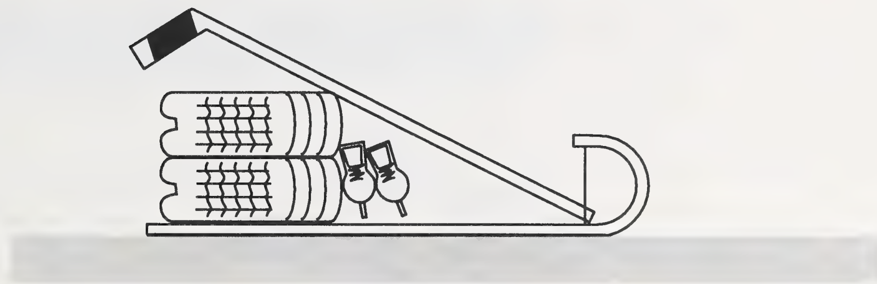
When Marc pulls on the toboggan rope, he actually exerts a vertical force and a horizontal force at the same time. This is what causes the rope to be pulled at an angle.



To simplify the situation, consider only the horizontal force.



10. Assuming that the toboggan moves with constant velocity, label the force of friction, the force of gravity, and the normal force on the diagram.



11. If the toboggan and hockey gear have a total mass of 12.5 kg, calculate the weight of the toboggan and hockey gear.

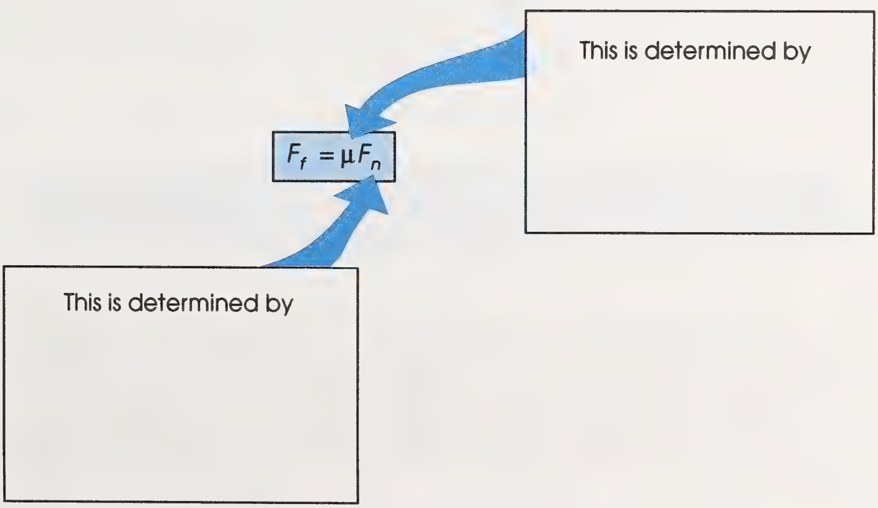
12. Define *normal force*.

13. What would be the value of the normal force on the toboggan? Explain your answer.

14. Define *coefficient of friction*.

15. What factors would determine the coefficient of friction for the toboggan?

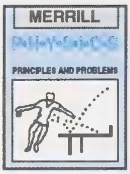
16. Earlier Marc asked, "What things influence the force of friction for my toboggan?" Answer his question by adding point-form descriptions to the following diagram.



17. What could Marc do to reduce the force of friction on his toboggan? Answer by referring to the equation $F_f = \mu F_n$.

Check your answers by turning to the Appendix, Section 2: Activity 1.

It is now time to make sure that you really understand the ideas of normal force, coefficient of friction, and force of friction. Carefully attempt each of the following problems. After you try each one, study the solution in the Appendix and correct your answers.



18. Do Practice Problem 9 on page 99 of your textbook.

A diagram can be very helpful when solving a problem. As you do the next few problems, start with a diagram that describes what is happening.

19. Do Practice Problem 10 on pages 99 and 100 of your textbook.

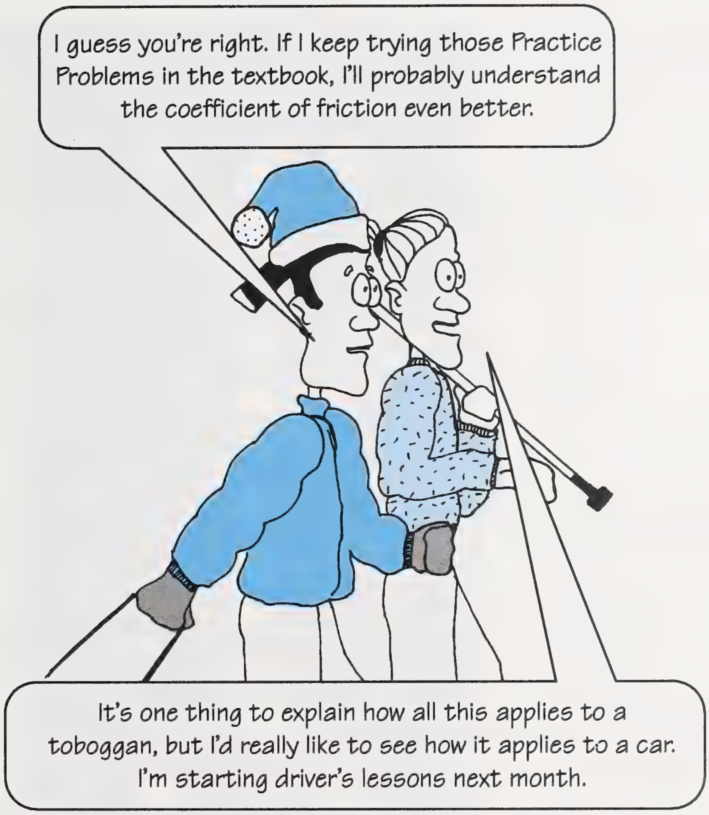
20. Do Practice Problem 11 on page 100 of your textbook.

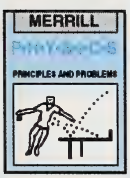
21. Do Practice Problem 12 on page 100.

Did you notice the importance of Newton's laws in understanding the normal force? You can say that according to Newton's second law, the weight must be balanced by some other force to produce zero acceleration.

The normal force is caused by the surface being compressed slightly beneath the object. Due to the elastic nature of the surface, the particles of the surface push up on the object, creating the normal force.

You should now have a better understanding of Newton's laws and how they apply to problems involving the coefficient of friction.





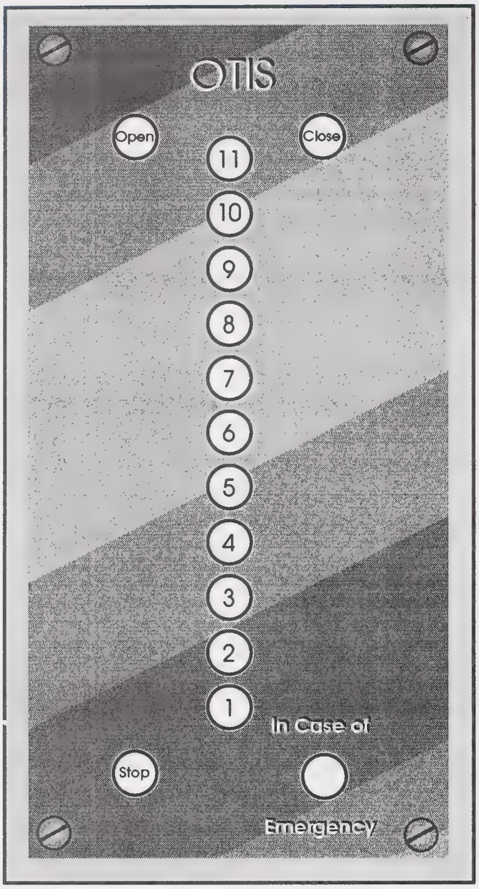
22. Do questions 14 and 16 on page 106 of your textbook.

23. Do questions 8 and 9 on page 691 of your textbook.

Check your answers by turning to the Appendix, Section 2: Activity 1.

In this activity you have seen how friction plays an important role in understanding many different processes. The study of friction began with Marie and Marc pulling the toboggan to the rink to play hockey. You will be exploring other ideas with Marie, Marc, and their other friends as they continue their walk to the outdoor rink and start to play hockey.

Activity 2: Going Up



In the last activity Marie and Marc were on their way to meet Cameron before going to the outdoor rink to play hockey.

Unfortunately, Cameron wasn't on time and Marc had to go into the high-rise apartment building where Cameron lives to get him out of bed. Since Cameron lives on the eighth floor, this meant using the elevator.

When was the last time that you used an elevator? You may remember the strange feelings from accelerating and decelerating each time the elevator stopped and started at a floor.

Newton's laws of motion explains what really happens during an elevator ride. In the next investigation you will analyse some of the changes that take place when elevators start and stop.

PATHWAYS

If you have access to the laser videodisc called *Physics: Cinema Classics* and a laser videodisc player, do Part A. If you do not have access to the laser videodisc, do Part B.

Part A

Investigation: An Actual Elevator Ride

Science Skills

- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

Purpose

In this investigation you will explore what happens when elevators start and stop.

Materials

You will need the following materials for this investigation:

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player with a bar code reader

If the laser videodisc player does not have a bar code reader, enter the frame number(s) listed on the icon to search and play the segments.

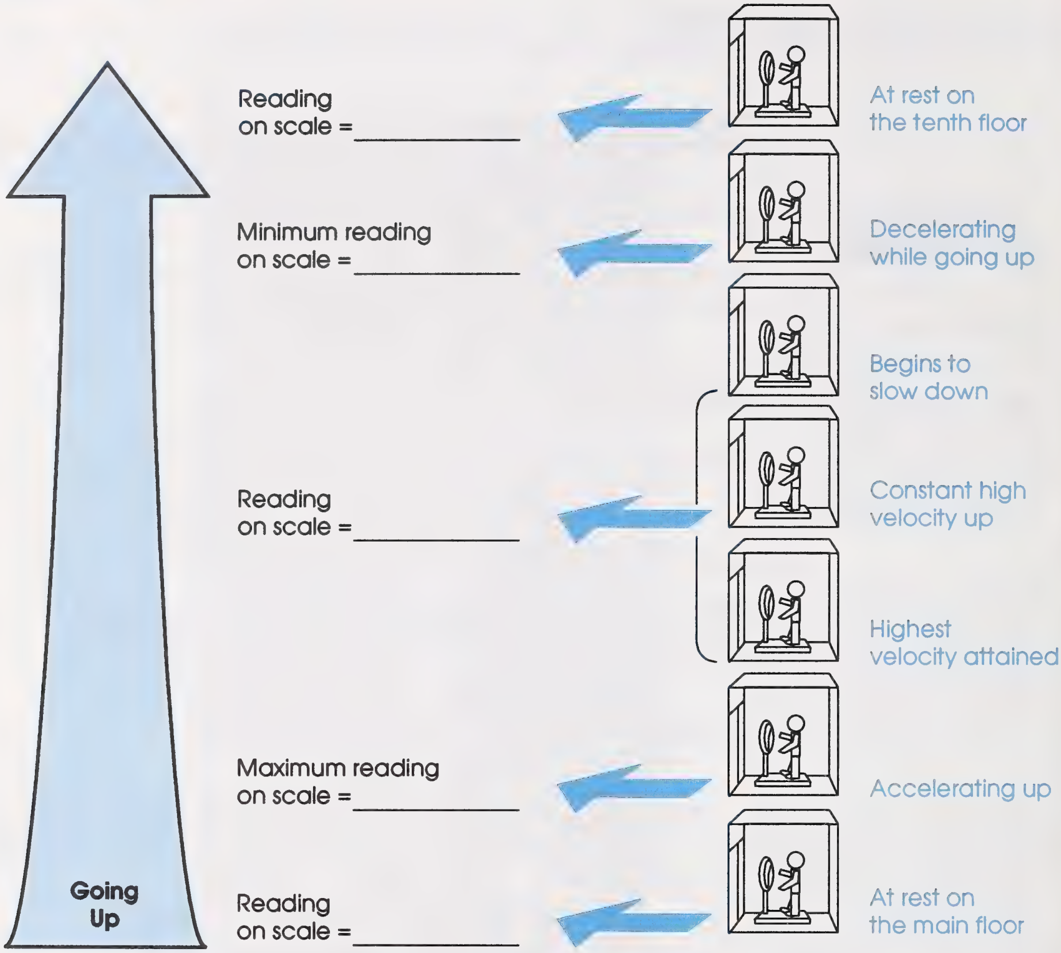
Procedure

- Load the laser videodisc called *Physics: Cinema Classics* Side A into the laser videodisc player and press "play". Use the bar code reader to watch the short video clip of a person going up in a high-speed elevator.

Frames 47479 – 48334

Observations

1. You should have noticed that the scale reading changed when the elevator started and stopped on the way up. To help you summarize what you saw, view the clip again and record the appropriate scale readings on the following graphic. Be sure to view the clip as many times as needed and to make use of the freeze frame and step function capabilities on your laser videodisc player so that you are able to record all the relevant data.



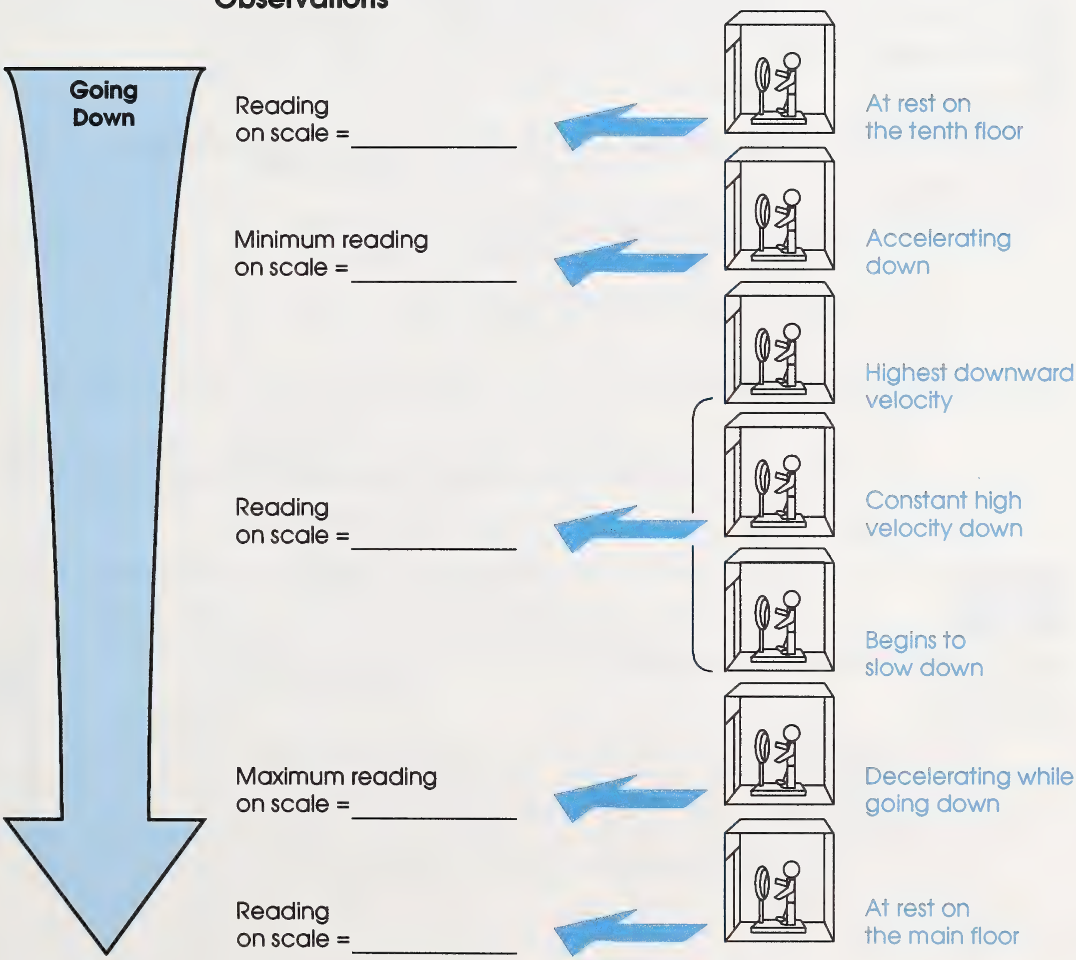
2. The readings on the scale were given in pounds. The accepted unit for force in SI metric units is the newton. To change the scale readings to newtons, multiply by 4.445 N/lb. Add the newton values to the chart.

- Use the bar code reader to watch the video clip of the same person going down in the same high-speed elevator.

Frames 48335 – 49008

3. Did you notice that the readings on the scale change on the way down as well? Use the same techniques as before to record the scale readings for the trip on the way down. Be sure to change the force values to newtons.

Observations



Reading on scale = ____________

Minimum reading on scale = ____________

Reading on scale = ____________

Maximum reading on scale = ____________

Reading on scale = ____________

- Complete the investigation by doing the questions following Part B.

End of Part A

Part B

Investigation: A Simulated Elevator Ride

Science Skills

- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

Purpose

In this investigation you will explore what happens when elevators start and stop using a homemade "elevator".

Materials

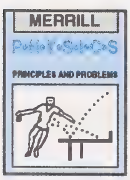
You will need the following materials for this investigation:

- a 10-N spring scale
- an empty pop can
- water
- 10 cm of masking tape

Procedure

- Securely attach the pop can to the spring scale with masking tape. Add water to the can until the scale reads 3.0 N for the weight of the can and the water. The pop can is your elevator.

- Follow the procedure given on page 98 of your textbook. Remember that you are using a 10-N scale and a 3.0-N weight instead of the materials described in the book, so substitute your materials as necessary.



Observations

4. Answer Observations and Data question 1 on page 98 of your textbook.

End of Part B

Conclusions

5. Answer Analysis questions 1, 2, and 3 on page 98 of your textbook.

6. Complete Applications questions 1 and 2 on page 98.

In this investigation you should have noticed that the values on the scale changed when the elevator started moving, slowed down, and stopped. Understanding these observations requires applying Newton's second law. Carefully read from the middle of page 100 to the middle of page 101 and then answer the questions that follow.

7. Figure 5-14 on page 100 of the textbook accompanies the explanation about net force on that same page.

   a. Throughout the explanation, which direction is considered positive and which is considered negative for the forces?

   b. Why is the force of friction -20 N and not $+20$ N?

8. Figure 5-15 on page 101 of the textbook accompanies the explanation about net force on that same page.

   a. Do a large freehand sketch of Figure 5-15.

   b. Indicate on your sketch which direction is positive and which direction is negative, and label the signs and sizes of the applied force, weight, and net force.

Study the Example Problem on page 101 in your textbook and attempt the questions that follow.

9. Do a freehand sketch of Figure 5-16 that accompanies the Example Problem. Note that part a and part b of the figure match part a and part b of the problem. Enhance the sketch by indicating which direction is positive, which direction is negative, and label the signs and sizes of all the forces mentioned in the Example Problem.

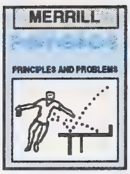
10. a. Refer to the solution for part a of the Example Problem on page 101. Use Newton's second law to explain why an acceleration of zero means that the net force must be zero.

    b. Use Newton's first law of motion to explain why an acceleration of zero means that the net force must be zero.

11. When basic equations were listed in the Example Problem on page 101, two equations were listed for the net force.

    a. What were the two equations for net force?

    b. Explain both equations.



12. To learn more about how Newton's second law can be used to explain the motion of elevators and other objects, attempt Practice Problems 13, 14, 15, and 16 on page 102 of your textbook. A diagram has been drawn for each of the Practice Problems.

Diagram for Practice Problem 13:

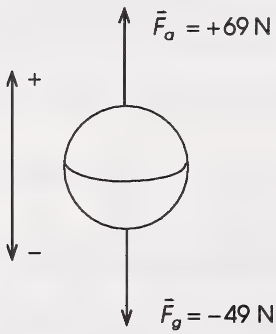


Diagram for Practice Problem 14:

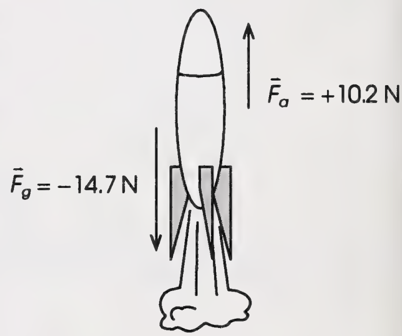


Diagram for Practice Problem 15:

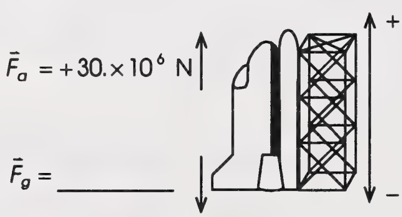
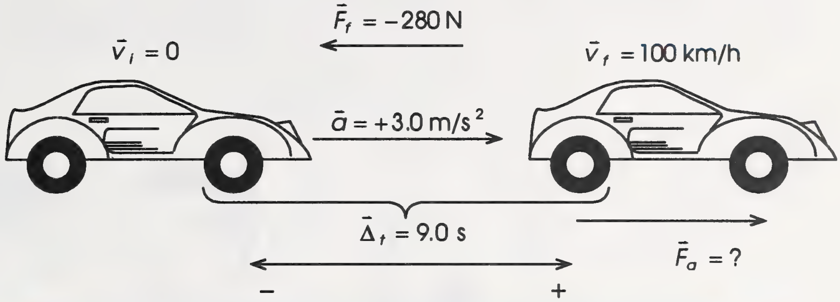
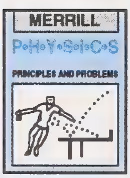


Diagram for Practice Problem 16:



Check your answers by turning to page 663 in your textbook.

13. How would you answer Cameron's question? Why don't large snowflakes accelerate at 9.80 m/s^2?



Confirm your answer to the last question by reading from the middle of page 102 to the middle of page 103 in your textbook.

14. Define *terminal velocity*.

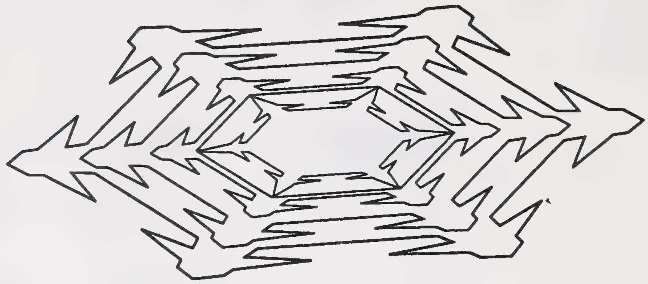
15. The reading in the textbook suggests using a piece of paper to demonstrate that the size and shape of an object will influence the force of air resistance. How could you do a similar demonstration with snow?

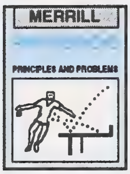
16. Turn to the photo of the skydivers on page 86 of your textbook. Think carefully about the question that is asked directly across from the picture. Then label the following diagrams with the appropriate forces and terminal velocities.

Falling through the air in the spread eagle position

Falling with the chute open

17. Use your explanation of the open parachute as a guide to explain the low terminal velocity of snowflakes. Label the diagram to assist with your answer.





18. Do problems 18, 19, 20, and 22 on page 106 of your textbook. Be sure to start each problem with a labelled diagram.

Check your answers by turning to the Appendix, Section 2: Activity 2.

In this activity you have seen how Newton's second law of motion can be applied to elevators and objects falling through the air. In the next activity you will see how all of Newton's laws can be applied to a variety of sporting events, especially hockey.

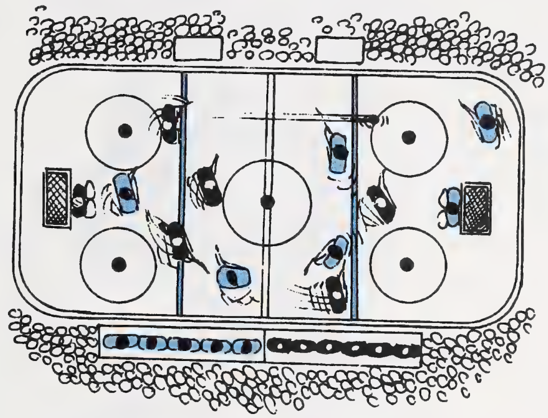
Activity 3: Newton's Laws in Terms of Momentum

Newton's laws are very much a part of your daily life. It is virtually impossible to think of an activity that doesn't have something to do with Newton's laws.

Hockey is a pastime that many people enjoy watching and playing. Hockey is also useful for studying Newton's laws because the ice reduces the complicating effects of friction.

1. Explain the caption under each diagram in terms of Newton's laws of motion.

a.



The puck travels with nearly constant velocity to the other end of the ice.

b.

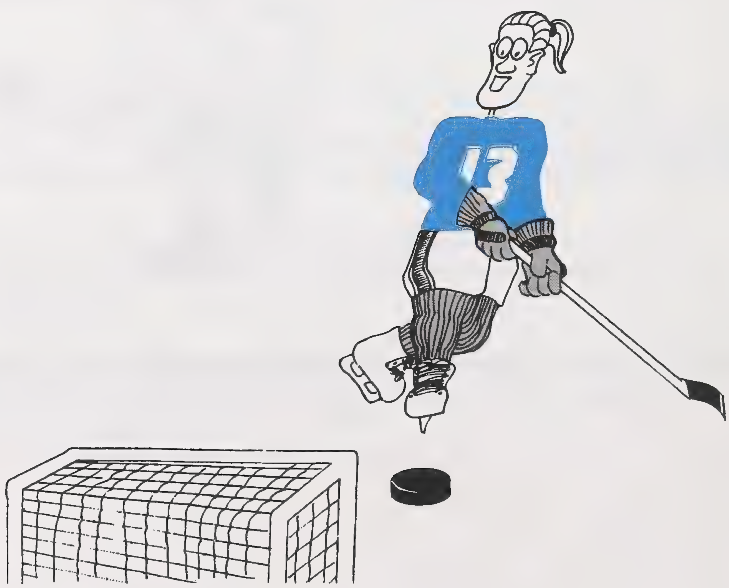
To force their bodies forward, players must push into the ice with their back skates.

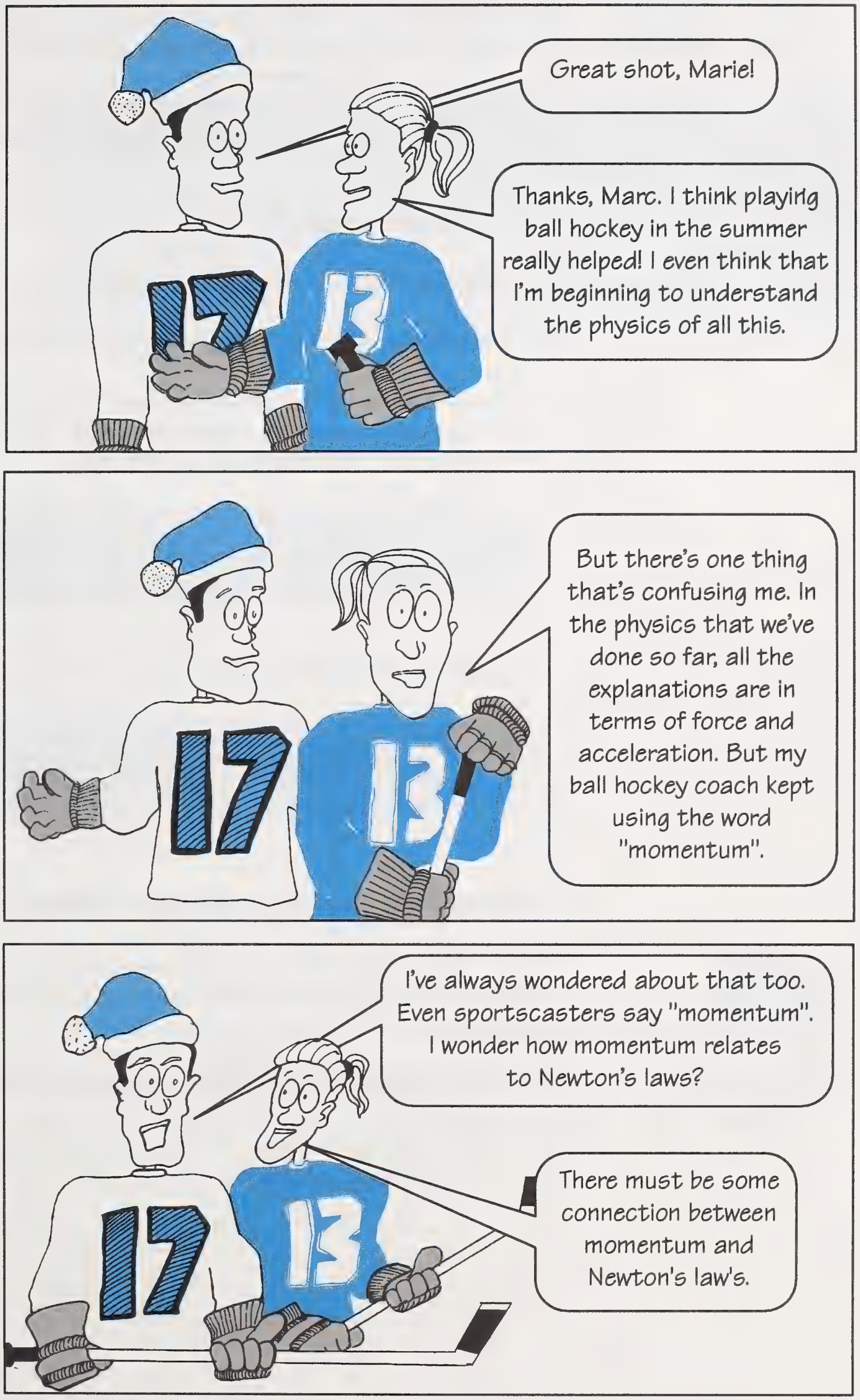
c.

If a puck is at rest, players must exert a force with their sticks to accelerate the puck to a high velocity.

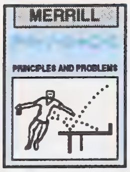
Check your answers by turning to the Appendix, Section 2: Activity 3.

You will see further applications to the sport of hockey as Marie, Marc and Cameron start to play.




Great shot, Marie!
Thanks, Marc. I think playing ball hockey in the summer really helped! I even think that I'm beginning to understand the physics of all this.
But there's one thing that's confusing me. In the physics that we've done so far, all the explanations are in terms of force and acceleration. But my ball hockey coach kept using the word "momentum".
I've always wondered about that too. Even sportscasters say "momentum". I wonder how momentum relates to Newton's laws?
There must be some connection between momentum and Newton's law's.

momentum – the product of the mass and the velocity of an object ($\vec{p} = m\vec{v}$)



The ideas that explain **momentum** are actually not that different from Newton's laws of motion. In fact, when Newton originally published his laws of motion, he explained each law in terms of momentum, not force and acceleration. To better understand the meaning of momentum, carefully read pages 174 through to the middle of page 176. Then answer the questions that follow.

2. Define *momentum*.

3. Describe an object that has a very small amount of momentum.

4. Describe an object that has a large amount of momentum.

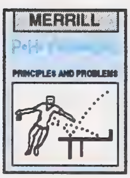
5. Study the Example Problem on the bottom of page 177. Which object has the greater quantity of motion, the baseball moving at 35 m/s or the bowling ball moving at 0.67 m/s? Explain.

Check your answers by turning to the Appendix, Section 2: Activity 3.

6. Complete Practice Problem 1 on page 178 of your textbook.

Check your answers by turning to page 669 in your textbook.

Newton's First and Second Laws in Terms of Momentum



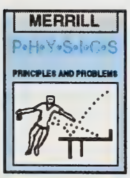
To see the connection between momentum and Newton's laws, read from the middle of page 176 to the middle of page 177. Then answer the questions that follow.

7. How could Newton's first law be written in terms of momentum?

8. Define *impulse*.

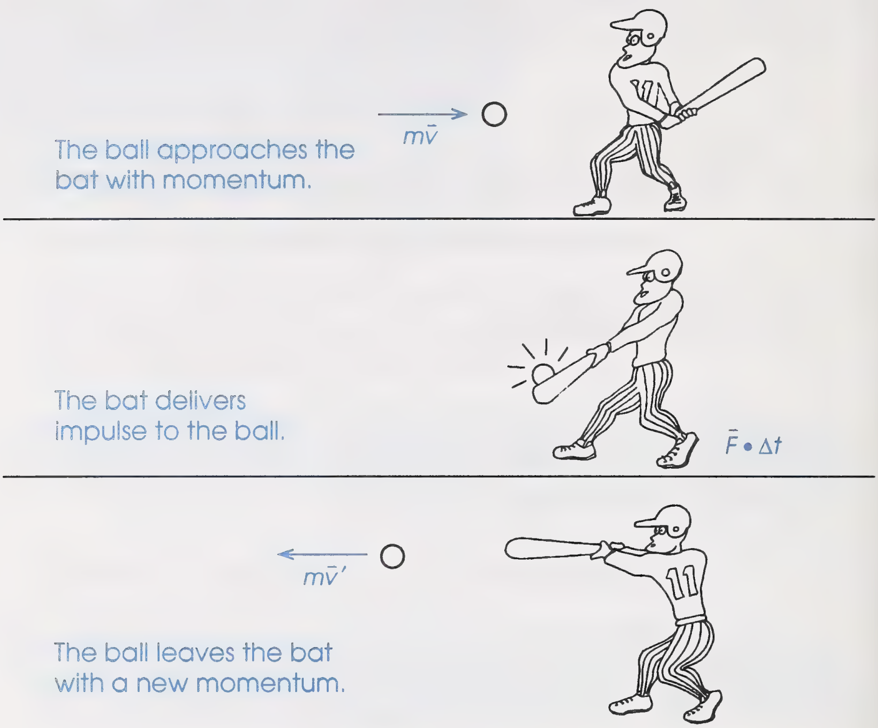
9. Use equations and brief descriptions to show how Newton's second law can be written in terms of change in momentum and impulse.

Writing Newton's Second Law in Terms of Momentum	
Equations	**Brief Description**
$\vec{F} = m\vec{a}$	Newton's second law



The main advantage of expressing Newton's laws in terms of momentum is that it allows you to compare the motion of the parts of a system before and after a complex interaction without having to explain what happened during the interaction. This makes it possible to predict very complicated outcomes without knowing all the circumstances during the event. The Example Problem on page 178 makes this point clear. Study this problem carefully and then answer the questions that follow.

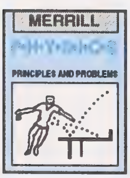
10. Figure 9-3 on page 178 accompanies the Example Problem. This figure has been simplified and represented here so that you could add some important labels.



a. Which direction is negative and which direction is positive for the data in the calculations? Answer by labelling the previous diagrams.

b. Use an arrow and a number to label the velocity of the ball before and after it is hit.

c. Use an arrow and a number to label the force exerted by the bat on the ball.



Impulse and change in momentum are ideas that baseball coaches might use to help you improve your technique on the field. The concepts of impulse and momentum can also determine whether or not you will survive a traffic accident! To discover this connection, examine the photo on page 174 and the question at the top of page 175 in your textbook. Then read the last half of page 177 and answer the questions that follow.

11. Use the definition of impulse to explain how an airbag and a seatbelt can save your life in a head-on crash.

Check your answers by turning to the Appendix, Section 2: Activity 3.

12. To deepen your understanding of momentum and impulse, do Practice Problems 2 and 3 on page 179 of your textbook. Diagrams have been provided to help you with your solutions.

Diagram for Practice Problem 2:

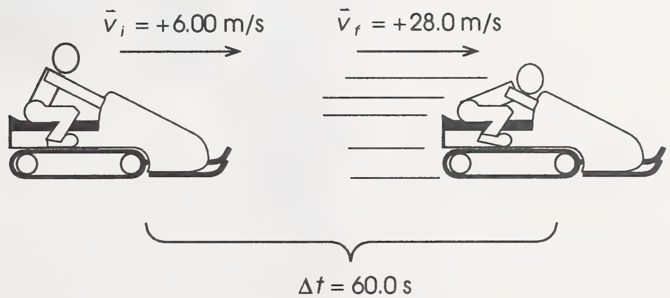
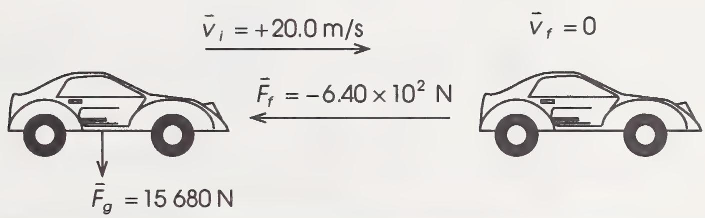
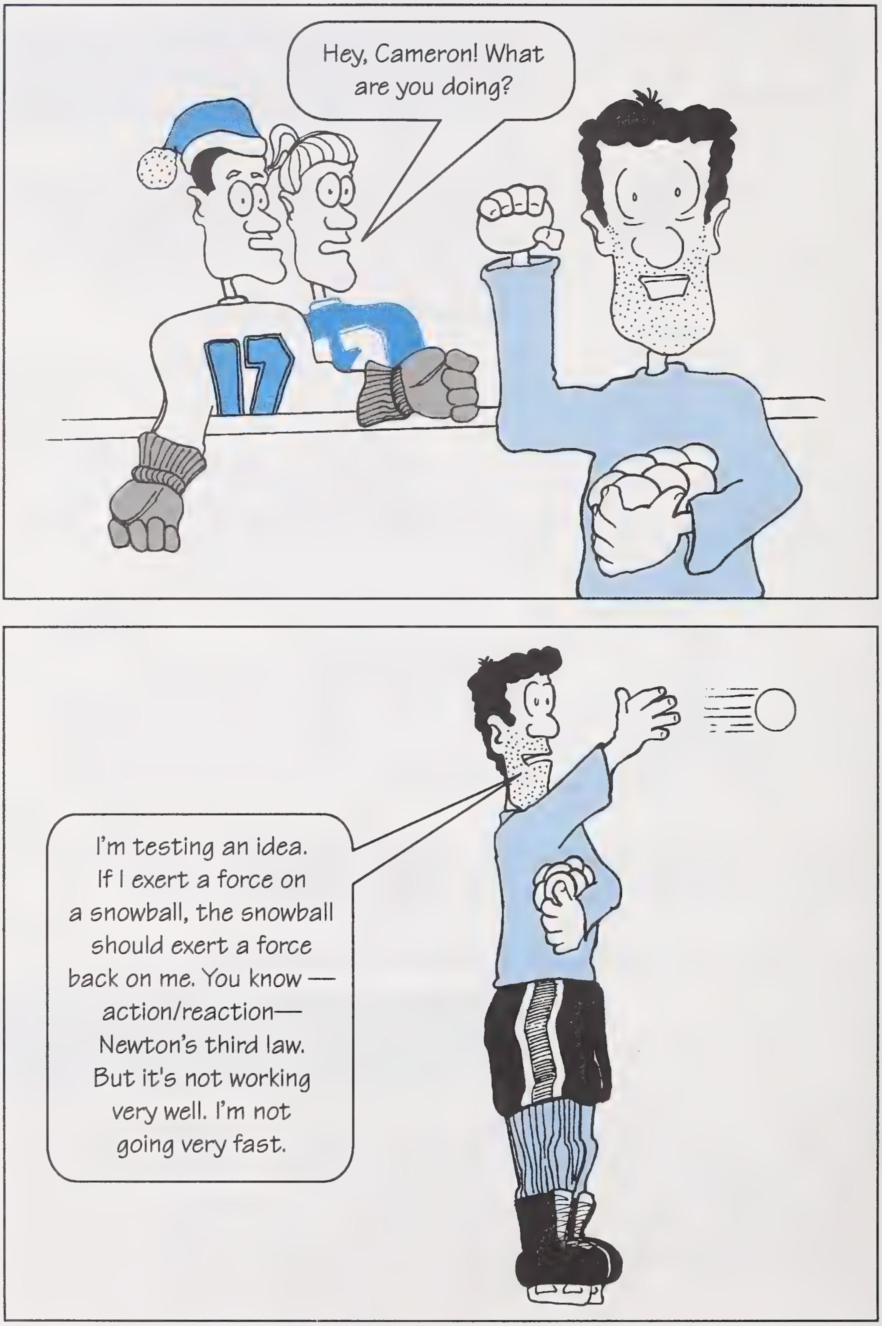


Diagram for Practice Problem 3:



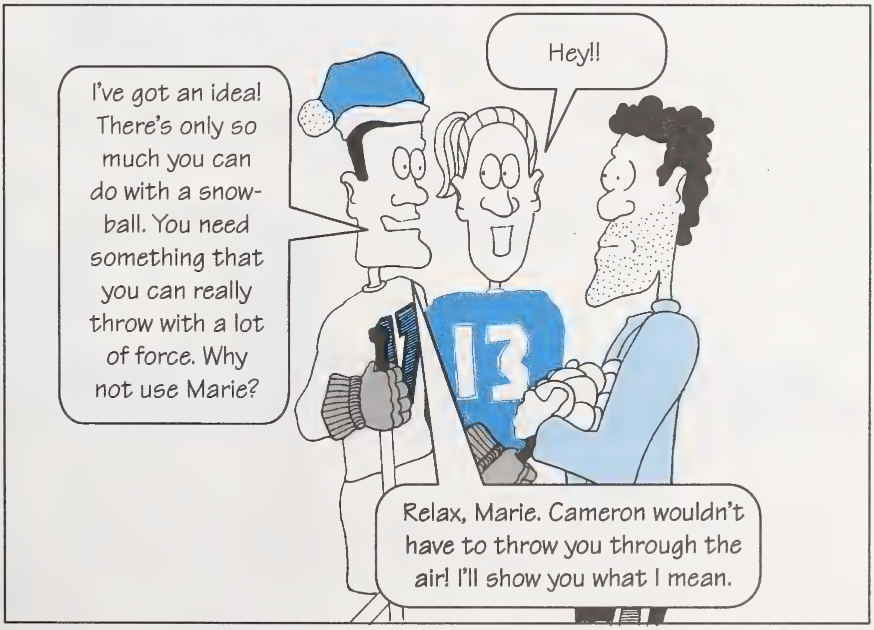
Check your answers by turning to page 669 in your textbook.

Newton's Third Law in Terms of Momentum



13. a. On the following diagram label the action-reaction pair for Cameron when the snowball is still in his hand.

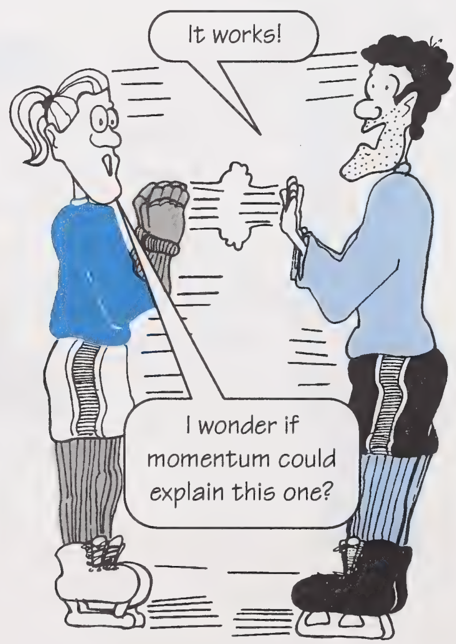
b. Why do you think Cameron isn't going very fast?



14. Assuming that Cameron is the only one who pushes, draw the action-reaction pair on the previous sketch.

15. If Marie was able to lock her arms firmly in place, what would happen when Cameron pushed?

Here is what it looked like when Marie and Cameron tried Marc's idea.



16. To answer Marie's question in the last cartoon, complete the following analysis that helps to express this situation in terms of momentum. Add the necessary explanations. The subscript M stands for Marie and the C stands for Cameron.

Writing Newton's Third Law in Terms of Momentum

Analysis	Explanation
$\vec{F}_{C \to M} = -\vec{F}_{M \to C}$	
$m_C(\vec{a}_C) = -m_M(\vec{a}_M)$	
$m_C\left(\frac{\Delta \vec{v}_C}{\Delta t}\right) = -m_M\left(\frac{\Delta \vec{v}_M}{\Delta t}\right)$	
$m_C(\Delta \vec{v}_C) = -m_M(\Delta \vec{v}_M)$	
$\Delta \vec{p}_C = -\Delta \vec{p}_M$	
$\vec{F}_{C \to M}(\Delta t) = -\vec{F}_{M \to C}(\Delta t)$	

17. State Newton's third law for the two skaters in terms of impulse, as given in the sixth equation in the previous chart.

18. State Newton's third law for the two skaters in terms of momentum, as given in the fifth equation in the previous chart.

MERRILL P•H•Y•S•I•C•S PRINCIPLES AND PROBLEMS

19. Do textbook question 23 on page 194 of your textbook.

Check your answers by turning to the Appendix, Section 2: Activity 3.

You can see how Newton's laws can be enhanced by introducing the idea of momentum. In the next section you will see how Newton's laws become even more useful when two-dimensional vectors are used.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. In this section you have been introduced to a number of new terms and equations. Summarize these ideas by completing the following chart.

Comparison Chart for New Terms

	Coefficient of Friction	Normal Force	Net Force	Momentum	Impulse
Symbol					
Brief Description					
Equations that Include this Term					

2. You have seen that Newton's laws can be expressed either in terms of force and acceleration or in terms of momentum and impulse. Summarize Newton's laws in both formats on the chart.

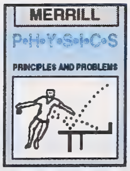
	Newton's Laws Comparison Chart	
	Described in Terms of Forces and Acceleration	**Described in Terms of Momentum and Impulse**
Newton's First Law of Motion		
Newton's Second Law of Motion		
Newton's Third Law of Motion		

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Do **one** of the following activities.

1. If you like to collect sports cards, you may enjoy this activity. Create a large poster illustrating Newton's three laws of motion with sports cards. Beside each card write a brief description of how the picture on the card illustrates one of Newton's three laws. Group all the cards for each of the laws together under a heading.



2. If you have access to laboratory facilities, do the lab investigation called The Explosion on page 182 of your textbook. Complete the Observations and Data questions and the Analysis and Applications questions.

3. If you have access to the booklet Critical Thinking which accompanies the teacher resource package for your textbook, do the activity on page 7 in that booklet. This activity allows you to apply your knowledge of forces to an airplane in flight.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

In this section you have seen that Newton's laws can be applied to a wide variety of situations. Most applications involve friction in one form or another. These laws also apply when objects are travelling in an elevator or while falling freely through the air.

You have also learned that Newton's laws can be stated in terms of momentum, instead of in terms of force and acceleration. The momentum approach provides valuable insights for understanding sports situations and automobile safety.

In the next section you will continue to see how ideas that you have already learned can be enhanced by the new point of view provided by a study of vectors.

Assignment Booklet

ASSIGNMENT

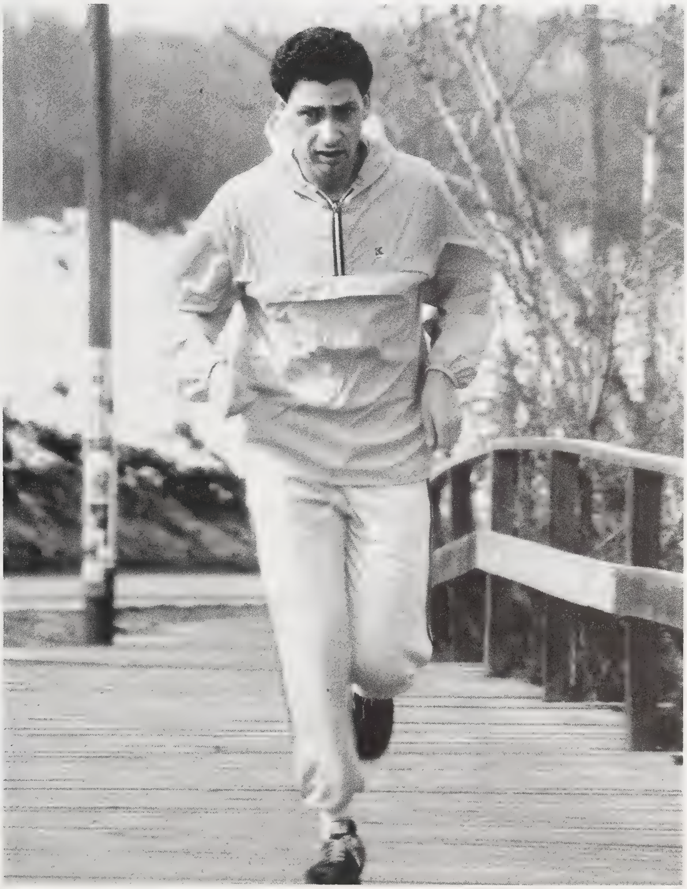
Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3 Vectors

Have you ever tried orienteering? Orienteering is a sport that involves following a map and using a compass to reach a certain destination. To be successful at orienteering, you not only need to be a fast runner, you also have to be able to figure out which way to go! The study of vectors is similar because direction is very important.

In this section orienteering examples are used to give you practice adding displacements, drawing vector diagrams, and working with force components.



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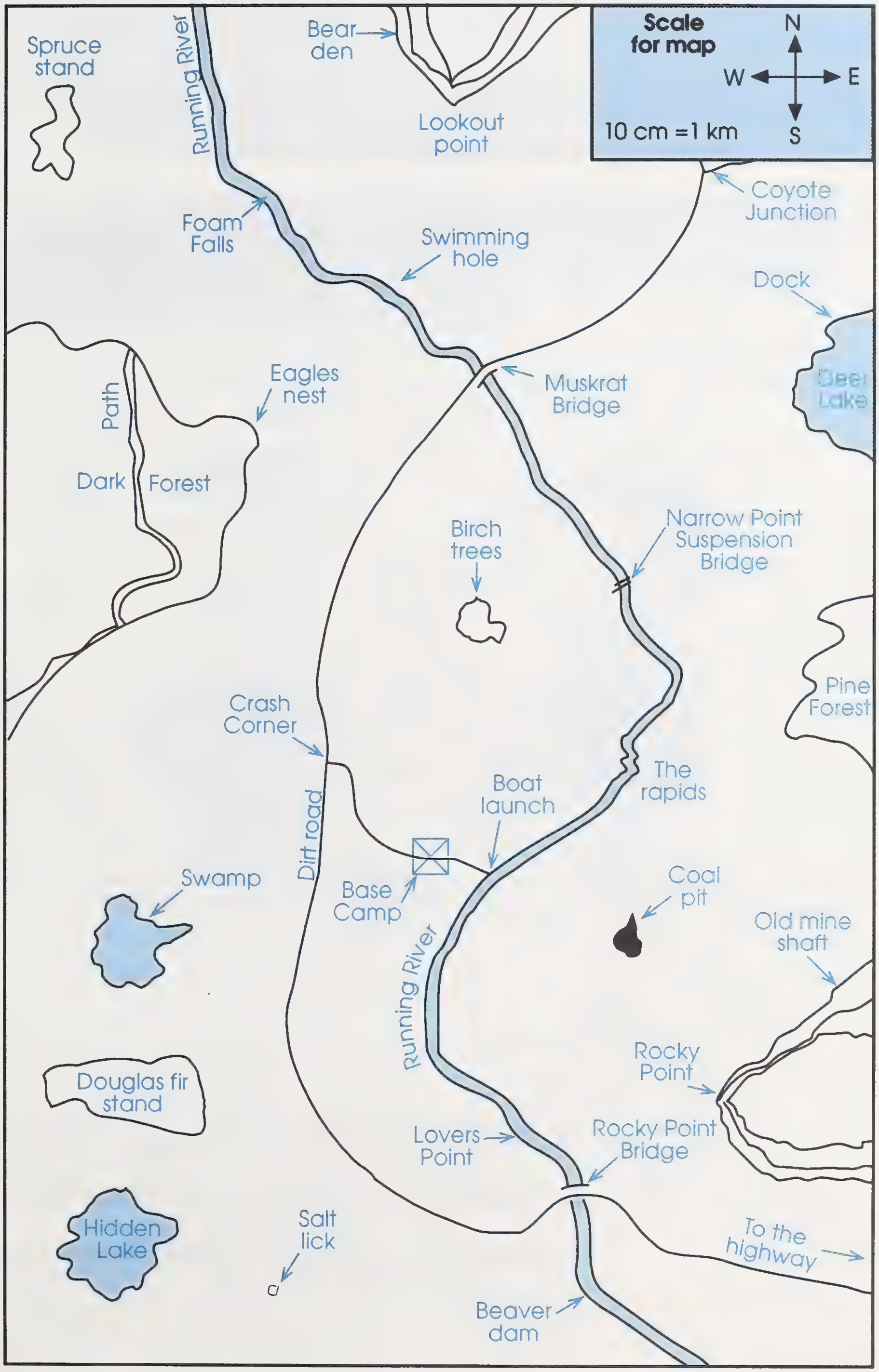
Activity 1: Mapping Madness

Cathy and David are doing an orienteering exercise for their physics course.

The map that Cathy and David will be using is shown on the opposite page. A scale has been indicated in the upper right corner of the map.

1. What distance from Crash Corner are Cathy and David expected to travel to find this message?

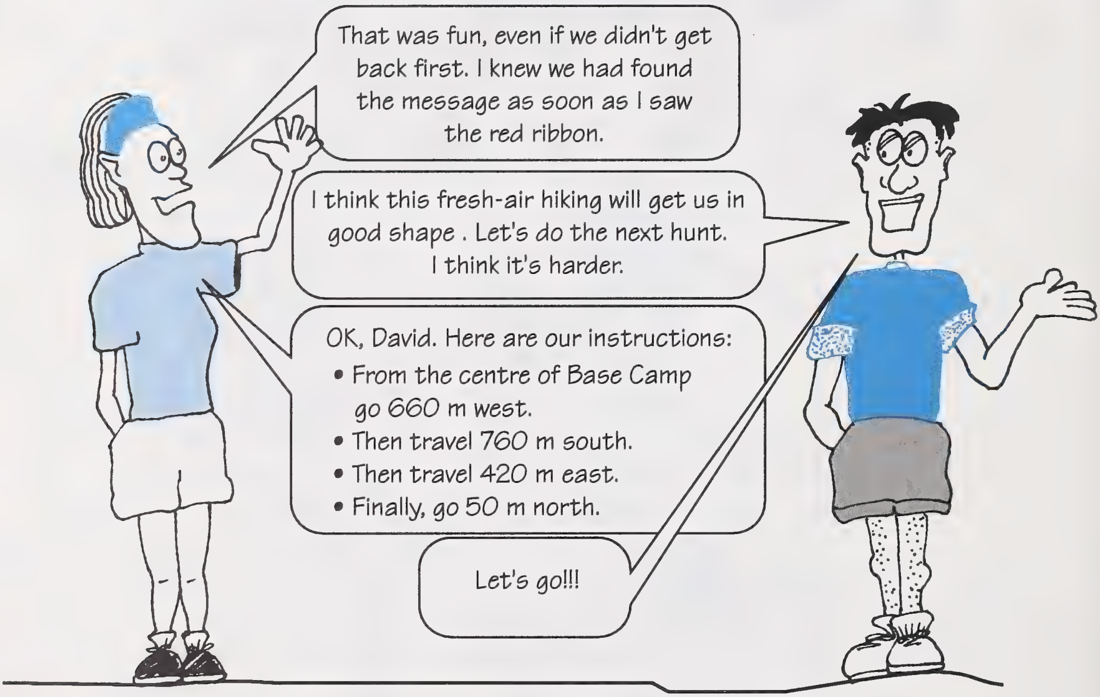

Scale
for map
10 cm = 1 km
N
W
E
S
Spruce stand
Running River
Bear den
Lookout point
Coyote Junction
Foam Falls
Swimming hole
Dock
Deer Lake
Muskrat Bridge
Eagles nest
Path
Dark Forest
Birch trees
Narrow Point Suspension Bridge
Pine Forest
Crash Corner
The rapids
Boat launch
Dirt road
Swamp
Base Camp
Coal pit
Old mine shaft
Running River
Rocky Point
Douglas fir stand
Lovers Point
Rocky Point Bridge
Hidden Lake
Salt lick
To the highway
Beaver dam

2. Describe where Cathy and David found the message.

3. What is the displacement from Crash Corner to where they found the message?

This message was left by Mr. Jones.

Message 1:	Congratulations! You've found the first message! Your orienteering is going well. You must be using your compass correctly.



4. What is the total distance to be travelled to get to Message 2?

5. Describe where David and Cathy will find Message 2.

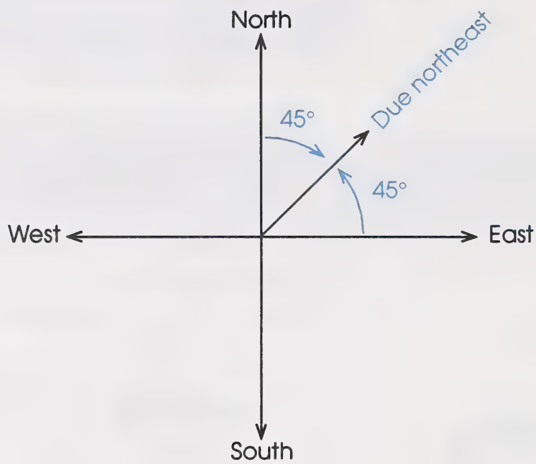
6. What is the displacement from Base Camp to Message 2?

7. If Cathy and David choose the shortest way back to Base Camp from Message 2, how long would that path be?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Message 2: You found me again! Good job! Now find a quicker way home.

Before you begin to map this route, here is a hint about using compass directions. Due northeast means exactly halfway between north and east.



Notice that since north and east form a 90° angle to each other, due northeast is 45° from due north and 45° from due east. It is often more convenient to abbreviate this direction by writing N45°E, which is read "from north go 45° east".

8. a. Draw a diagram that shows the direction due southeast. Label angles on the diagram as was done in the previous example.

   b. How could you abbreviate this direction?

Now you are ready to find the location of the third message. Answer the following questions when you finish.

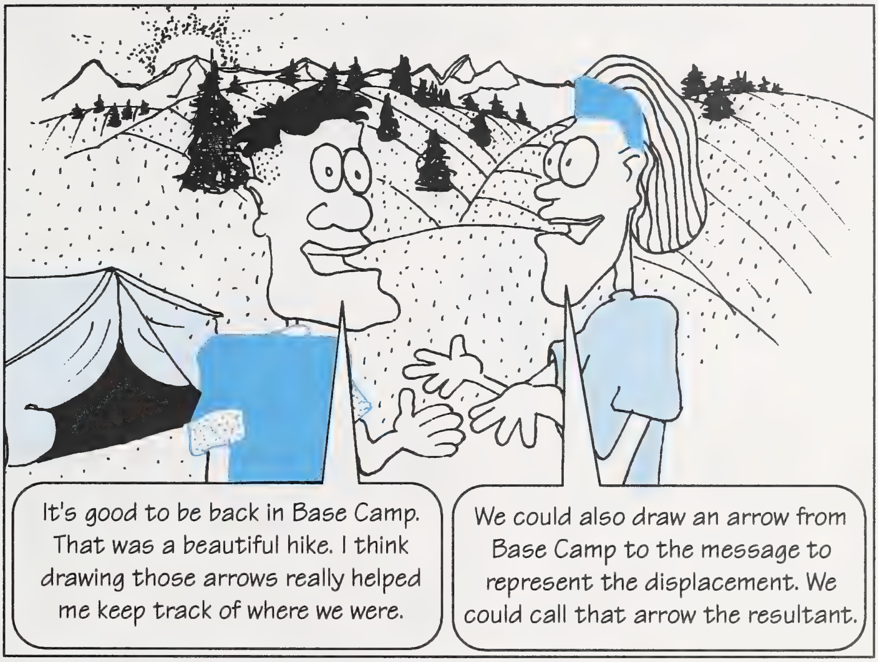
9. Determine the total distance travelled and the location of the third message.

10. What is the displacement from Base Camp to Message 3? Simply measure with a ruler on the map. Be sure to include an indication of direction that measures the angle from due north.

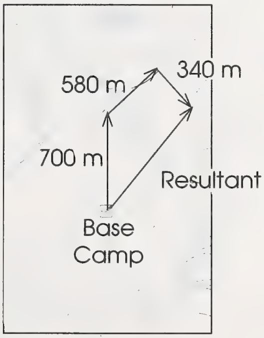
11. Which river crossing should Cathy and David use to take the shortest way back to Base Camp?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Message 3: Right on, team! Return home via the Narrow Point Suspension Bridge.

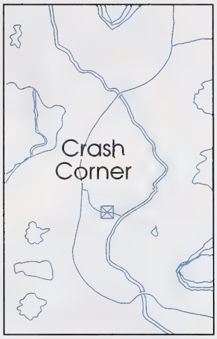


This is what Cathy and David's map looked like after drawing all the arrows and indicating the resultant.



12. Design a set of instructions to lead the team south from Crash Corner and across the Rocky Point Bridge to the old mine shaft. Be sure to use four arrows and don't just follow the road because there are usually bears on the road!

13. Summarize the details of your route by showing the four arrows and the resultant arrow.



14. a. Calculate the magnitude of the resultant arrow by measuring with a ruler on the larger original version of the map. Then check your measurement by using the Pythagorean theorem.

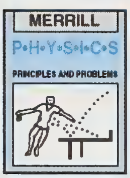
    b. Measure the angle of the resultant with a protractor. Check your answer by using trigonometry.

Check your answers by turning to the Appendix, Section 3: Activity 1.

In the next activity you will learn that these arrows can also represent velocities and forces. You will then begin an in-depth study of vectors and learn how mapping techniques can be applied to solving problems.

Activity 2: Drawing Vectors

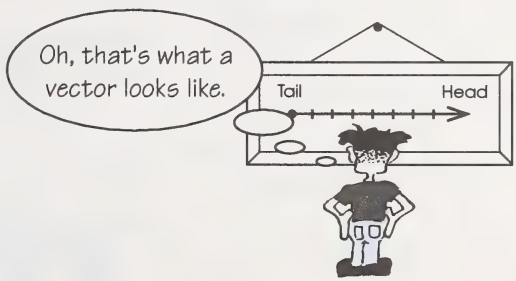
vector – a measured quantity that has both magnitude (size) and direction



You can learn more about drawing **vectors** by reading page 110 of your textbook. Then answer the following questions.

1. How is the magnitude of a vector represented?

2. How is the direction of a vector represented?

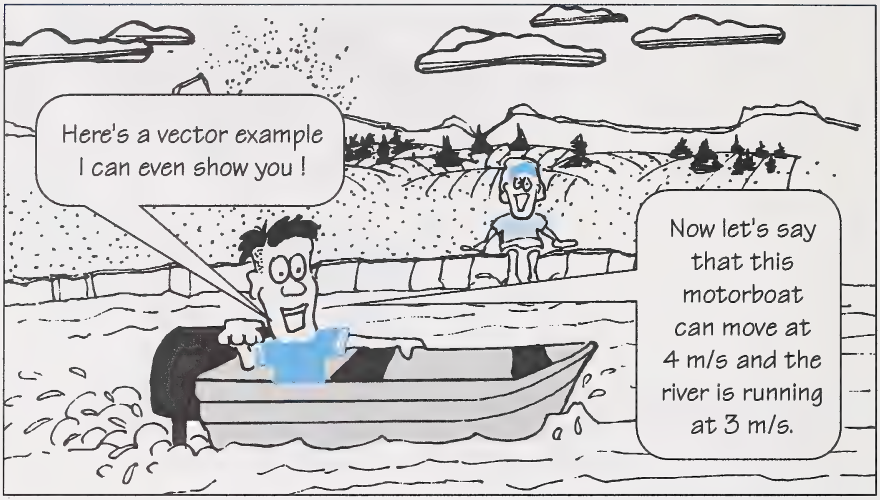


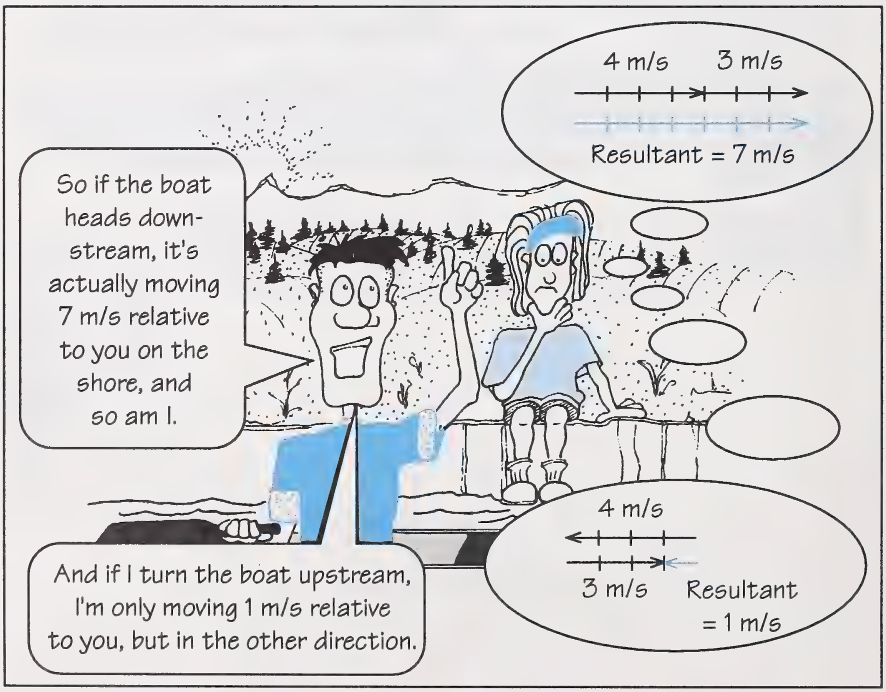
3. What is the general rule that is followed when adding vectors?

4. Define *resultant vector*.

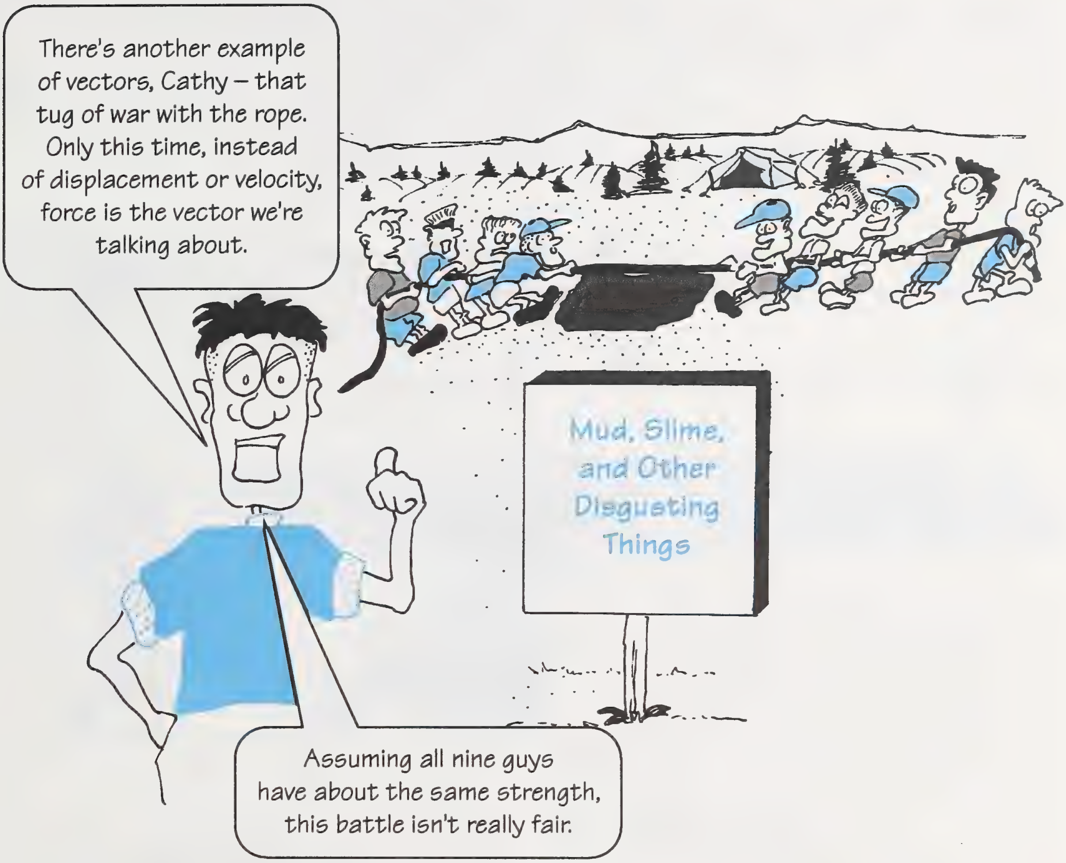
5. What is the general way to draw the resultant of vectors?

Check your answers by turning to the Appendix, Section 3: Activity 2.

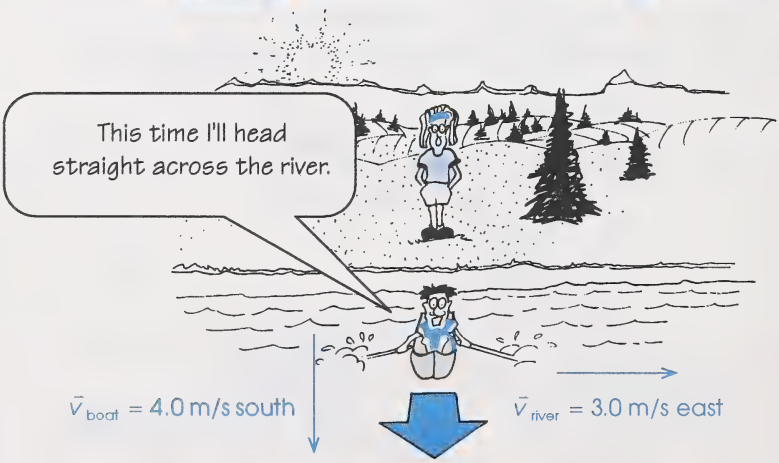


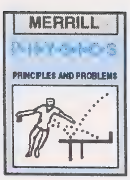


6. Is the resultant different if you add the vectors in a different order? Use the previous example to help you answer.



7. Use the graphical method of vector addition to show the resultant of the tug of war example.





David's motion can again be represented with vectors. Read the section titled Vector Addition in Two Dimensions on pages 110 and 111 of your textbook.

8. Show how the resultant of David's motion across the river can be determined by adding vectors on a diagram.

9. Because these two vectors are at right angles to each other, what formula could be used to calculate the magnitude of the resultant?

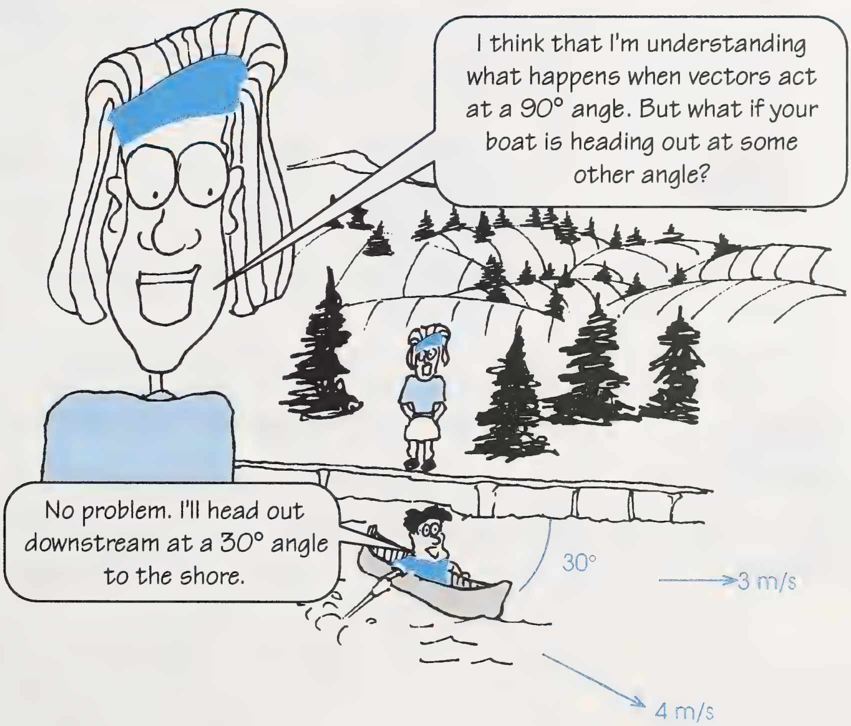
10. a. What is the magnitude of the resultant?

    b. What is the direction of the resultant? Express your answer with an angle.

This is a good time for you to see how well you have understood the techniques of vector addition. The next question will let you practise the use of the main ideas of vector addition.

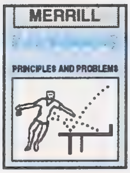
11. Turn to the Applying Concepts questions on page 128 of your textbook and do questions 1 to 5.

Check your answers by turning to the Appendix, Section 3: Activity 2.



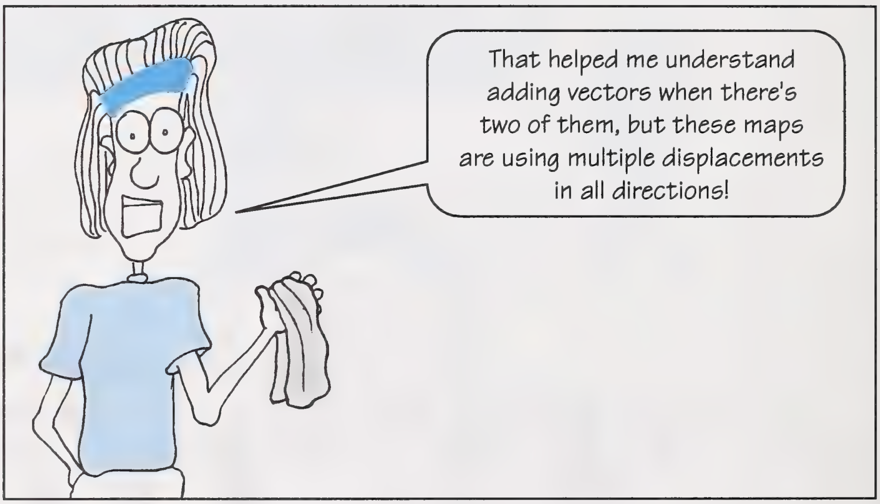
12. Use a metric ruler and a protractor to add the two vectors mentioned in the previous illustration (use the scale 1 cm = 1 m/s). Then find the magnitude of the resultant by measuring. Finally, find the direction of the resultant using the protractor. Work carefully with a sharp pencil.

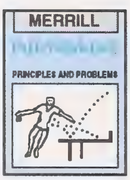
Check your answers by turning to the Appendix, Section 3: Activity 2.



13. Page 716 of your textbook gives you a quick review of the laws of cosines and sines. Once you have finished reading, try question 12 again using these equations instead of measuring. It really is a more accurate way of adding vectors!

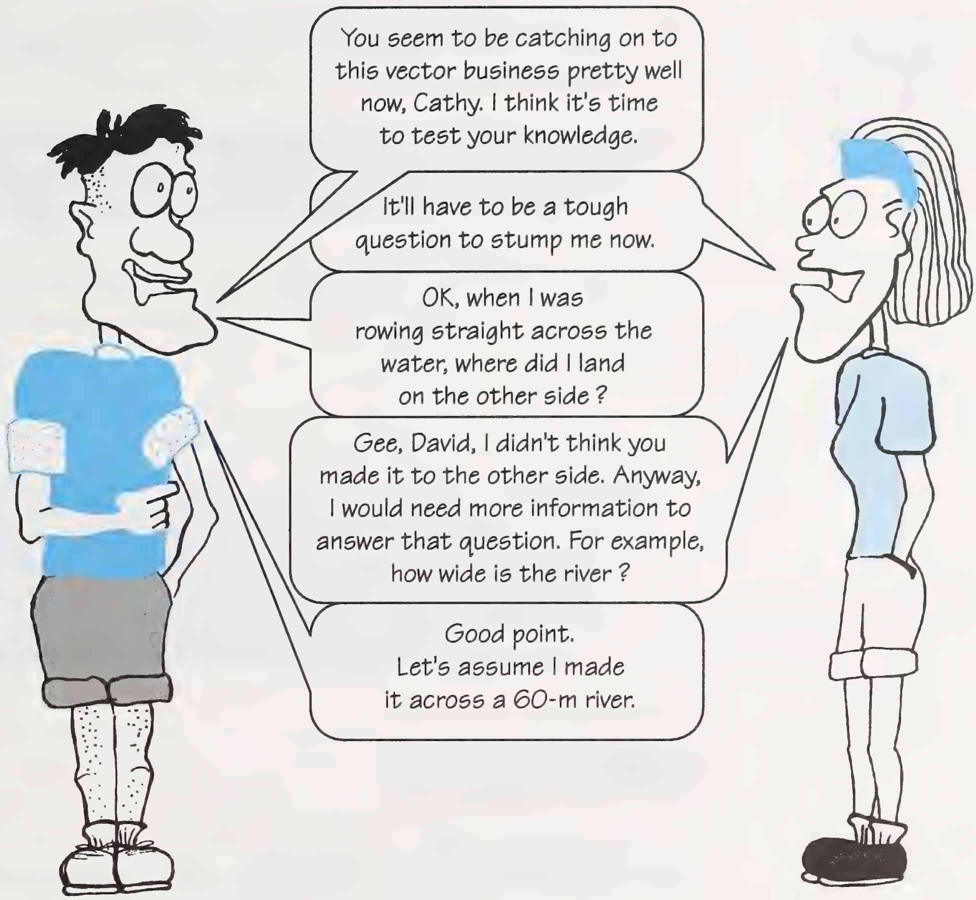
Finding the Resultant for More than Two Vectors

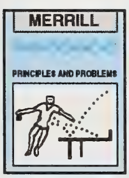




Read page 111 of your textbook to learn how to add several vectors.

14. Do Practice Problems 1 to 3 on page 112.

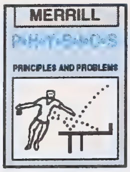




Read the section titled Independence of Vector Quantities on page 112 of your textbook. Then do the following question.

15. Assume that David can move at 4 m/s south while crossing the 60-m wide river which is flowing east at 3 m/s. Where will he dock on the other side? Draw a diagram.

The idea of independence of motion means that no matter how fast the river flows, the only thing that determines how long the boat will take to cross is its own velocity relative to the water. Practise using this concept as you solve the next question.



16. Do Practice Problem 4 on page 112 of your textbook. Be sure to begin with a labelled diagram and solve with the Pythagorean theorem and trigonometry.

Check your answers by turning to the Appendix, Section 3: Activity 2.

The concept that two velocity vectors can act independently of each other and influence the motion of an object is so important that you will do an investigation to verify it. You can also verify David's river journey without getting wet!

PATHWAYS

If you have access to the laser videodisc called *Physics: Cinema Classics* and a laser videodisc player, do Part A. If you do not have access to the laser videodisc, do Part B.

Part A

Investigation: River Crossing

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Purpose

In this investigation you will verify that two velocity vectors can act independently of each other on the same boat to produce a resultant velocity.

Materials

You will need the following materials for this investigation:

- the laser videodisc called *Physics: Cinema Classics*
- a laser videodisc player
- a sheet of clear thick (at least 1 mil) plastic large enough to cover the screen of the television
- at least two different coloured permanent markers.

If your laser videodisc player does not have a bar code reader, use the frame numbers provided with the icon to search and play each sequence.

Procedure and Observations

- Load the laser videodisc called *Physics: Cinema Classics* Side A into the videodisc player and press "play". Use the bar code reader to watch the entire series of clips of the motorboat crossing the river.

Frames 36398 – 38580

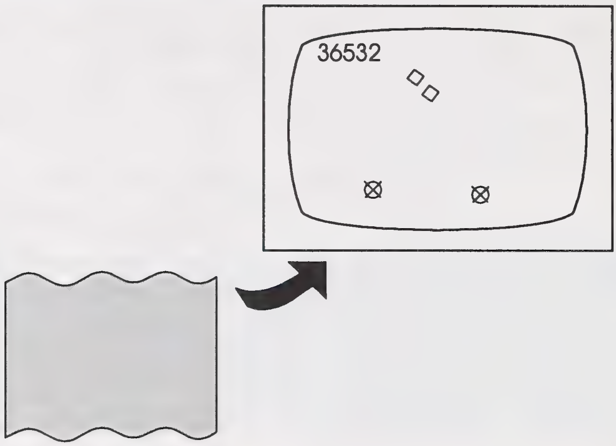
- The first thing to determine will be the velocity of the river. This can be done using the clip of the two floats being dropped into the water. Use the bar code reader to watch this clip.

Frames 36500 – 36903

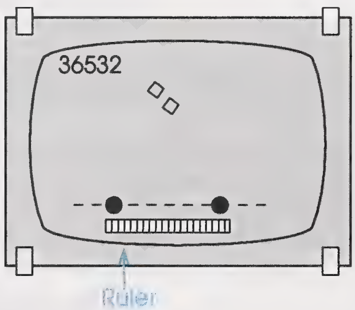
Frame 36532

17. Use the following steps to determine the velocity of the river. You will need to use the bar code reader to freeze the frame showing the fixed buoys and the moving floats. You will then use the step function capabilities as you work through the calculations.

Step 1: Tape the plastic over the TV screen.



Step 2: Mark the location of the two fixed buoys with a felt pen.

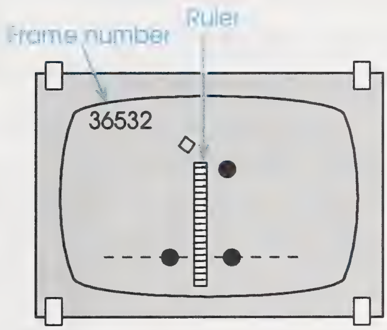


Step 3: Measure the separation of the buoys in metres. Use this measurement to calculate the magnification factor of your TV screen.

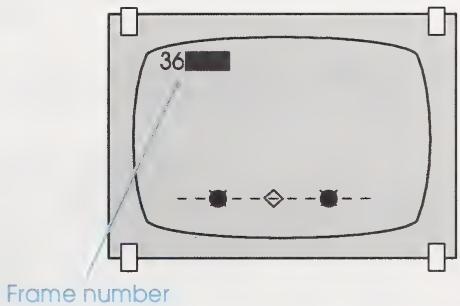
$$\text{magnification} = \frac{10 \text{ m (on river)}}{\boxed{}\text{ m (on TV)}}$$

$$= \boxed{}$$

Step 4: Mark the position of the moving float on the right. Record the frame number. Measure the distance in metres from the float on the right to the line between the fixed buoys.



Step 5: Use the step function to determine the frame number when the marker passes between the buoys.



Step 6: Use the fact that there are 36 frames per second to calculate the actual velocity of the river. Assume the direction of the river is south.

Check your answers by turning to the Appendix, Section 3: Activity 2.

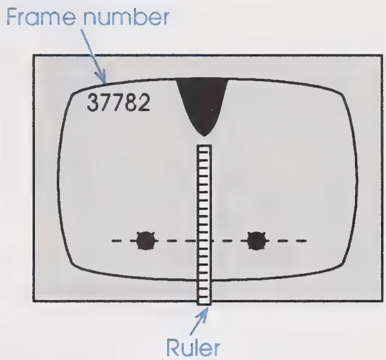
- The next thing to determine is the velocity of the boat. Use the bar code reader to view the clip of the boat travelling downstream.

Frames 37782 – 37906

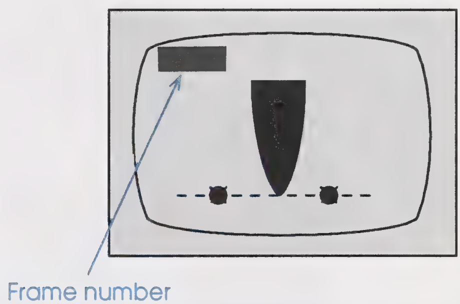
Frame 37782

18. Use the following steps to determine the velocity of the boat. You will need to use the bar code reader to freeze the frame showing the boat about to move downstream. You will then use the step function capabilities as you work through the calculations.

Step 1: Measure the separation in meters between the bow of the boat and the midpoint between the buoys.



Step 2: Use the step function to determine the frame number when the bow of the boat passes between the fixed buoys.



Step 3: Use the fact that there are 36 frames per second to calculate the actual velocity of the boat moving downstream.

Step 4: Use the velocity of the river to calculate the velocity of the boat.

- Now you are ready to predict what will happen when the boat travels east across the river which is flowing south. Use the bar code reader to view the clip of the boat travelling across the river.

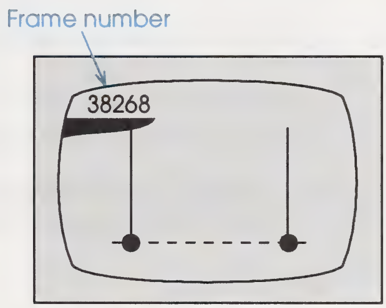
Frames 38052 – 38567

19. Use your earlier answers of the velocity of the river and the velocity of the boat to predict the resultant velocity of the boat as it travels across the river.

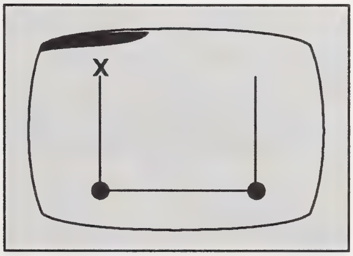
Frame 38268

20. Verify your prediction by using the following steps to measure the actual resultant velocity of the boat. Note that you will need to use the bar code reader to freeze the frame showing the first position of the boat. You will then use the step function capabilities as you work through the calculations.

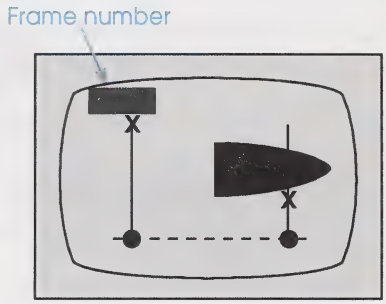
Step 1: Use a ruler to draw the lines shown. Be sure to draw the two vertical lines perpendicular to the line between the fixed buoys.



Step 2: Mark the location where the boat crosses the first vertical line.



Step 3: Use the step function to determine the frame number when the **same part of the boat** crosses the second vertical line. Mark this location.



Step 4: Calculate the resultant velocity of the boat moving across the river. Include an angle for direction.

Conclusion

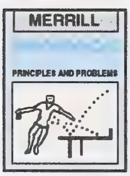
When you calculated the resultant velocity of the boat for question 19, you had to use two values that you calculated earlier. The velocity of the river was determined by observing two floats. The velocity of the boat was determined by subtracting the velocity of the river.

In other words, the resultant velocity of the boat was calculated from two other vectors which were independent of each other.

21. How would you account for any discrepancies between the predicted value and the actual value?

End of Part A

Part B



Turn to page 114 of your textbook and do The Paper River lab.

Science Skills

- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

Investigation: Crossing a Paper River

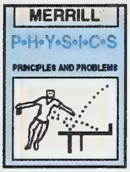
Purpose

In this investigation you will demonstrate the independence of perpendicular vector quantities.

Materials

If you don't have a little car which moves at uniform speed, you could substitute a marble for the car. Use a large marble because it will have more inertia than a small marble. You will need a marble launcher. A marble launcher is provided for you at the end of the Appendix. You will need to cut it out and fold it as indicated. You will probably need to use tape to hold it up in the correct position.

Procedure



- Follow the steps outlined on page 114 of your textbook. Note that you may need to modify if you are using a marble to represent the boat.

Observations and Data

22. Do Observations and Data questions 1, 2, 3, and 4 on page 114 of the textbook.

Analysis

23. Do Analysis questions 1, 2, and 3 on page 114 of the textbook.

Applications

24. Do Applications question 1 on page 114 of the textbook.

End of Part B

Science Skills

- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [ ] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

You have seen how vectors can be applied to reading maps while orienteering and when thinking about a boat crossing a river. Are these the only applications of vectors?

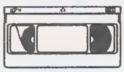
You will have a chance to answer this question in the next part of the activity. You will also have an opportunity to discuss the main ideas that have been introduced in this section.

PATHWAYS

If you have access to the video tape called *Vectors*, do Part A. If you do not have access to this tape, do Part B.

Part A

Watch the video and answer the following questions.



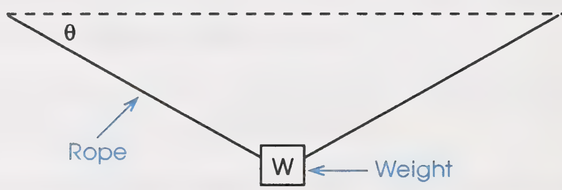
25. What two things must all vectors contain?

26. Give four examples of vector quantities.

27. Instead of saying that vectors are added "head to tail", what expression is used on this video?

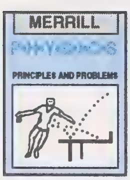
28. To move straight across a fast-moving stream, how should you aim your boat?

29. To decrease the tension in this rope what should you do?



End of Part A

Part B



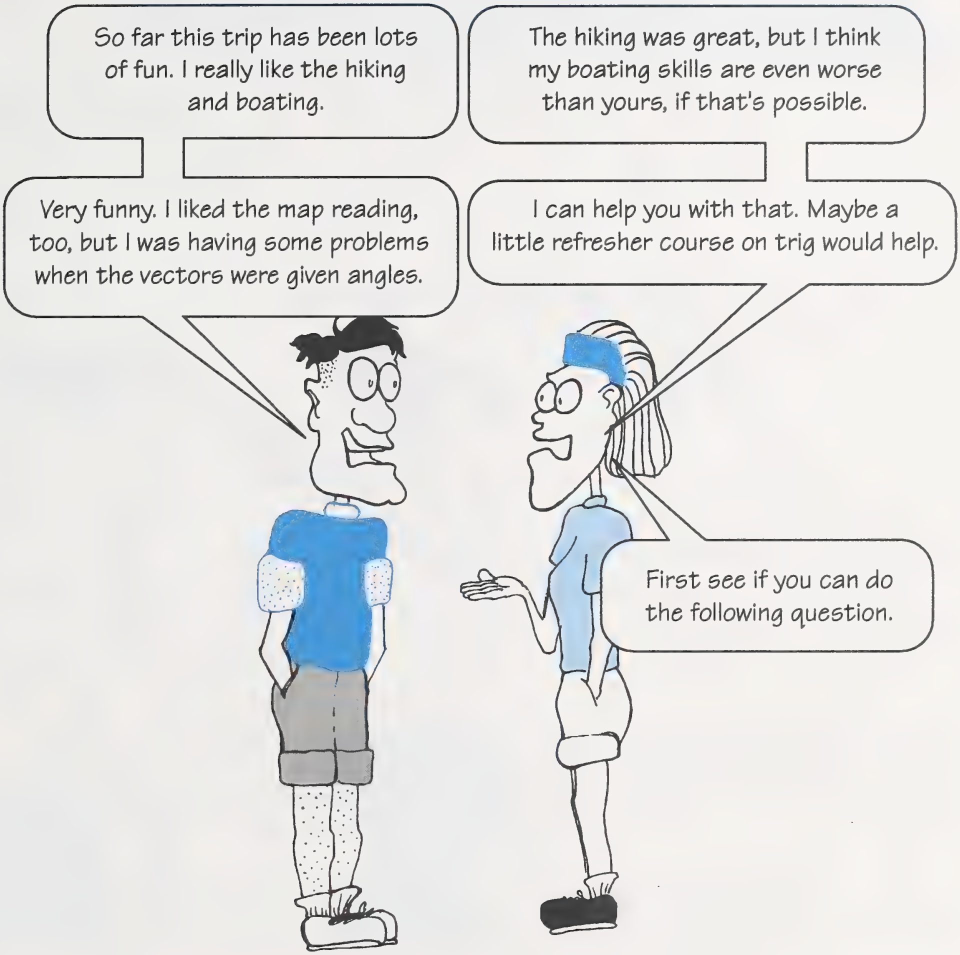
Open your textbook to page 127 where the Chapter 6 Summary is given. Study the points listed in the first column of this summary and then attempt the following questions.

30. Do Reviewing Concepts questions 1, 2, 3, and 6 on page 128 of your textbook.

End of Part B

Check your answers by turning to the Appendix, Section 3: Activity 2.

Activity 3: Components of Vectors

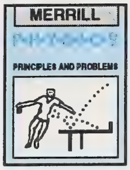


1. A light airplane flies north at 232 km/h while a strong wind blows out of the west at 65 km/h. Calculate the magnitude and direction of the airplane's velocity.

2. Study section 6.2 on pages 113 and 115 of the textbook to help you do problems 9 and 10 on page 129. Begin each problem by drawing a diagram.

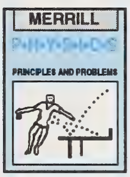
Check your answers by turning to the Appendix, Section 3: Activity 3.


OK. I think I have the trig under control now, but sometimes I have trouble getting started on the question.
I think you should always start with a diagram whenever you can. I always do and it always helps.
I'll try that. Sometimes I'm not sure how to write the angle on my answer. How do you handle angles ?
There are numerous ways to indicate direction. Sometimes it's relative to the ground or shoreline and sometimes it's north, south, east, or west. It depends on the question.
For example, consider the boat travelling as indicated in the following diagram.
N
W
E
S
20°
It's direction could be called W20°S or S70°W or 200° (counterclockwise from the x-axis).



3. You can practise measuring direction from different reference points by doing problems 18, 19, and 20 on page 130 of your textbook.

Check your answers by turning to the Appendix, Section 3: Activity 3.



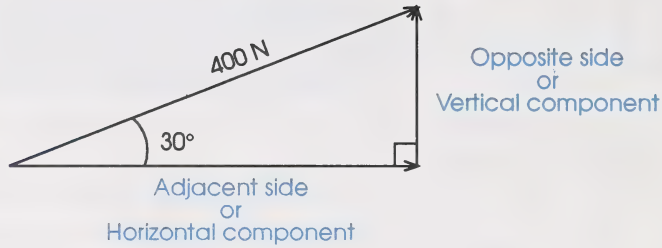
For David to fully understand the answer to his question, he would need to understand how vectors can be resolved into horizontal and vertical components. For a good introduction to vector components, read pages 116 and 117 of your textbook.

Note that the textbook once again uses equations that imply the multiplication and division of vectors. As explained in Module 1, you should use the scalar version of these equations. The scalar versions follow.

$$\sin\theta = \frac{F_v}{F} \qquad \cos\theta = \frac{F_h}{F}$$

$$F_v = F(\sin\theta) \qquad F_h = F(\cos\theta)$$

David pulls the rope with a force of 400 N at an angle of 30° to the horizontal. You can illustrate this as follows:



The opposite side to the angle is called the **vertical component**, or sometimes it is called the y-component.

The adjacent side to the angle is called the **horizontal component**, or sometimes it is called the x-component.

The components of the applied force can be found using trigonometry.

Find the vertical component.

$$\sin\theta = \frac{F_v}{F_a}$$

$$\sin 30° = \frac{F_v}{400\ \text{N}}$$

$$F_v = (\sin 30°)400\ \text{N}$$

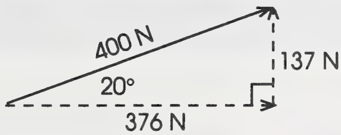
Find the horizontal component.

$$\cos\theta = \frac{F_h}{F_a}$$

$$\cos 30° = \frac{F_h}{400\ \text{N}}$$

$$F_h = (\cos 30°)400\ \text{N}$$

Now I'm beginning to understand.
I'll resolve my pulling force into horizontal and vertical components. So, if I pull with a force of 400 N at an angle of 20° to the ground, the horizontal component is



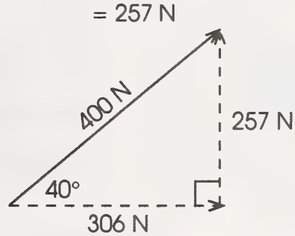
$$F_{\text{horizontal}} = 400(\cos 20°) = 376\text{ N}$$

and the vertical component is $F_{\text{vertical}} = 400(\sin 20°) = 137\text{ N}$.

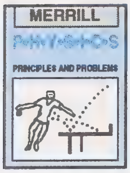
But, if I pull at an angle of 40°

$$F_h = 400(\cos 40°) = 306\text{ N}$$

$$F_v = 400(\sin 40°) = 257\text{ N}$$

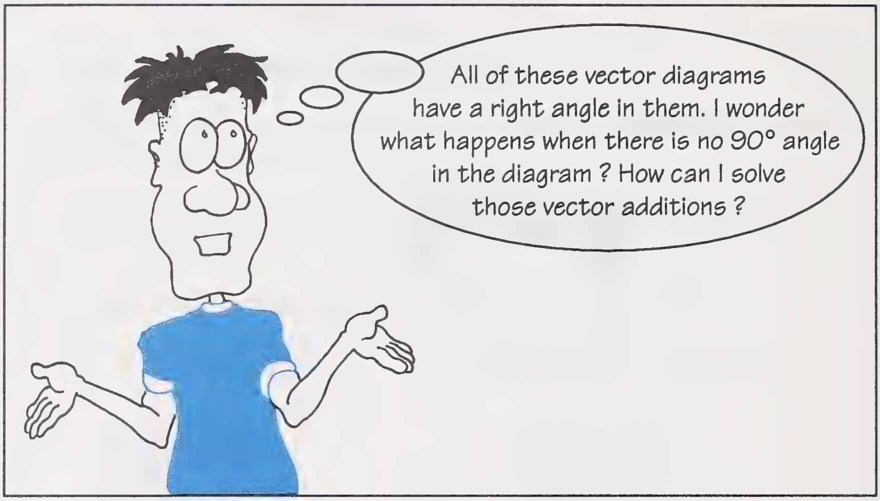


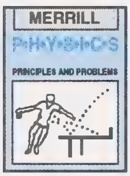
So, at a bigger angle I'm doing a lot more lifting and not as much pulling. That would explain why I'm using different muscle groups at different angles. These vectors are coming in handy already!



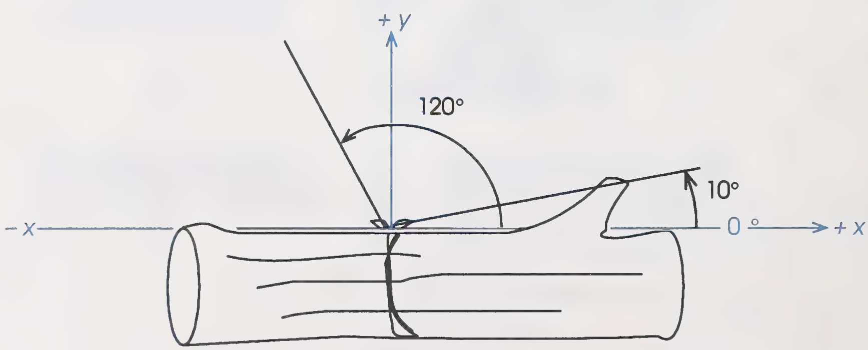
4. Do problems 21, 22, 23, and 24 on page 130 of your textbook. Remember to always start with a diagram and to use the scalar versions of the equations when finding vertical and horizontal components.

Check your answers by turning to the Appendix, Section 3: Activity 3.





Study page 119 of your text to gain insight into David's question. Read through the Example Problem several times so that you thoroughly understand it. The Example Problem uses the vector version of the equations – something that you should not do. The angles are measured according to the following system:



This system of measuring angles is also used in Math 20 and Math 30. In this system (the rectangular polar coordinate system), angles are measured counterclockwise from the *x*-axis. The *x*-axis is considered to be the horizontal direction and the *y*-axis is considered to be the vertical direction.

5. Here are some questions about the Example Problem on page 119 in your textbook.

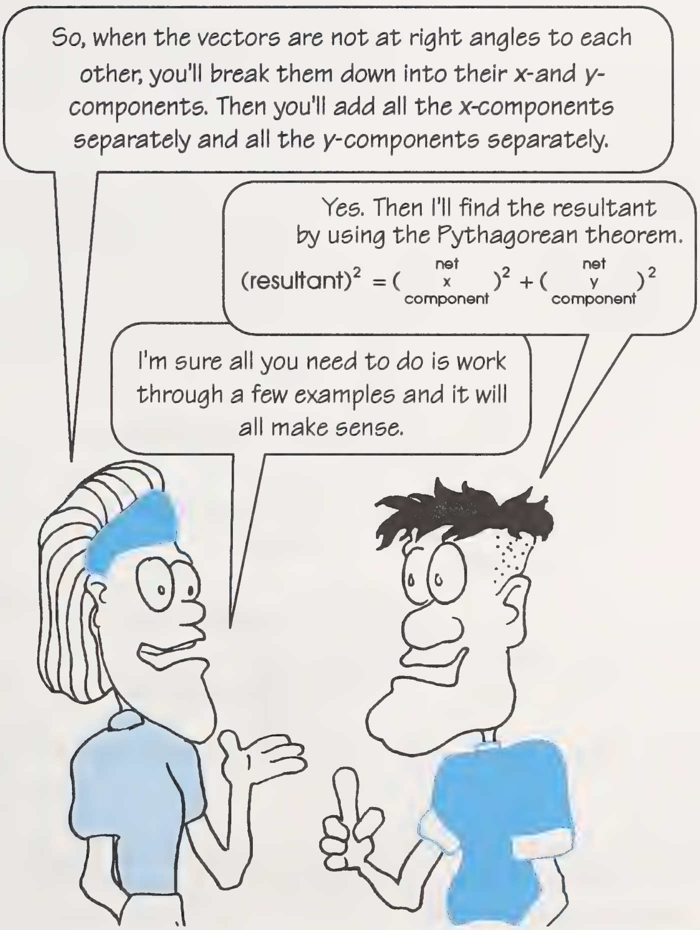
    a. The Example Problem asks you to find the net force on the log. What's another way to say "net force"?

    b. What's another way to say "horizontal component of the force"?

    c. When you add the x-component of Force 1 (F_{1x}) to the x-component of Force 2 (F_{2x}), what do you call this sum?

    d. What can $F_{1y} + F_{2y}$ be called?

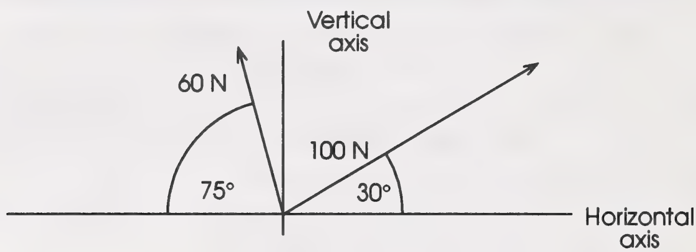
    e. What equation is used to find the net force from the net x- and y-components?



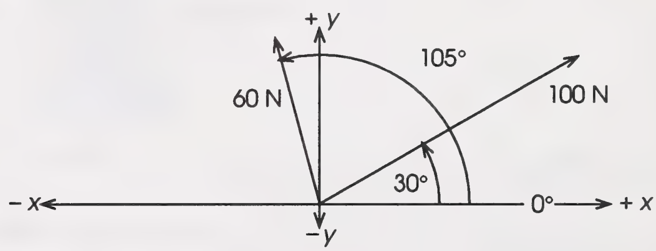
Here's another example to help you get started with resolving vectors into components.

Example

Consider the following two vectors. Find the resultant.



- Label the axes in terms of *x*- and *y*-coordinates with angles measured counterclockwise from the *x*-axis. Notice how the *x*- and *y*-axes are labelled as being positive and negative.



- Resolve the 100-N vector into its components.

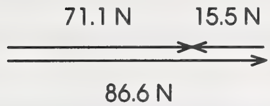
$$F_x = 100\ \text{N}(\cos 30°) = 86.6\ \text{N} \qquad F_y = 100\ \text{N}(\sin 30°) = 50\ \text{N}$$

- Resolve the 60-N vector into its components.

$$F_x = 60\ \text{N}(\cos 105°) = -15.5\ \text{N} \qquad F_y = 60\ \text{N}(\sin 105°) = 58\ \text{N}$$

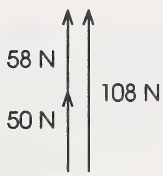
- Add the x-components.

$$86.6\ \text{N} + (-15.5\ \text{N}) = 71.1\ \text{N}$$



- Add the y-components.

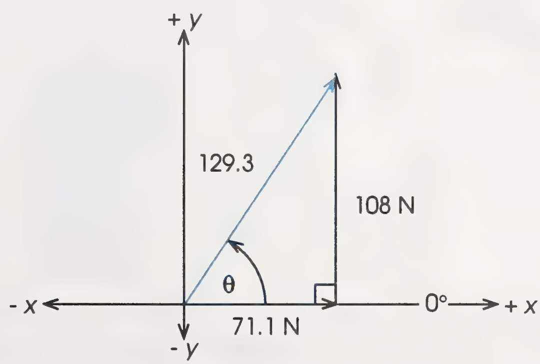
$$50\ \text{N} + 58\ \text{N} = 108\ \text{N}$$



- Use the Pythagorean theorem and trigonometry to find the resultant.

$$\begin{aligned} A^2 + B^2 &= C^2 \\ (71.1\ \text{N})^2 + (108\ \text{N})^2 &= C^2 \\ C &= 129.3\ \text{N} \\ &= 1.3 \times 10^2\ \text{N} \end{aligned}$$

$$\begin{aligned} \tan\theta &= \frac{\text{opposite}}{\text{adjacent}} \\ \tan\theta &= \frac{108}{71.1} \\ \theta &= 56.6° \\ &= 57° \end{aligned}$$



The resultant of the two forces is 1.3×10^2 N directed 57° up from the horizontal.

6. A light airplane travels at 286 km/h, N22°E while a 48-km/h wind blows directly from the west. Calculate the magnitude and direction of the resultant velocity by resolving the vectors into x- and y-components.

7. Two tugboats pull on a freighter. One tugboat pulls east with 430 kN while the other pulls N30°W with 260 kN. Use vector resolutions to find the magnitude and direction of the resultant force.

8. A hiker walks 4.8 km, E15°N and then walks 7.2 km, N38°W. Use vector resolutions to find the magnitude and direction of the resultant displacement.

Check your answers by turning to the Appendix, Section 3: Activity 3.

equilibrium – Forces are in equilibrium when the vector sum of all the forces acting is zero.

You will explore the solution to this problem by doing the following investigation. The key to this investigation is recognizing that the forces are in **equilibrium**.

Investigation: Forces in Equilibrium

Science Skills

- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [ ] E. Synthesizing
- [ ] F. Evaluating

Purpose

In this investigation you will confirm the laws of vector addition by observing a set of three forces in equilibrium.

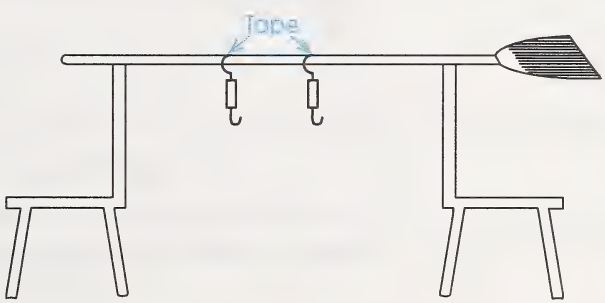
Materials

You will need the following materials for this investigation:

- long stick (a broom handle would work fine)
- 355-mL empty pop can
- two 10-N spring scales
- masking tape
- protractor

Procedure

- Position the long stick so that it is horizontal by balancing it on two chairs. It is important for the long stick to be as level as possible.
- Hang the spring scales over the stick and tape them down about 25 cm apart.

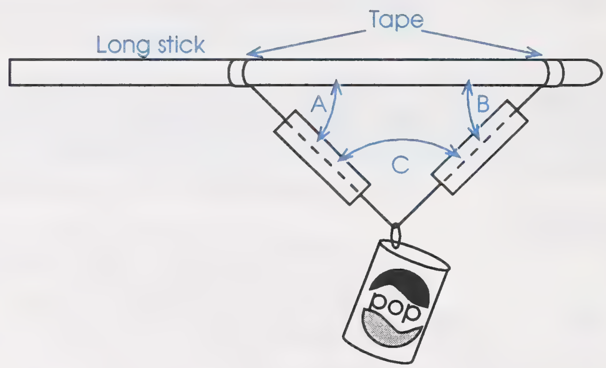


- Fill the empty pop can with water. The mass of the pop can filled with water should be approximately 370 g. The weight of the can and water can be calculated as shown.

$$F_g = mg$$
$$F_g = (0.370\ \text{kg})(9.80\ \text{m/s}^2)$$
$$= 3.6\ \text{N}$$

- Hang the water-filled can from the spring scale by the tab. The reading should say 3.6 N. You may have to make some adjustments to make the scale read 3.6 N.

- Hook both spring scales up to the can.



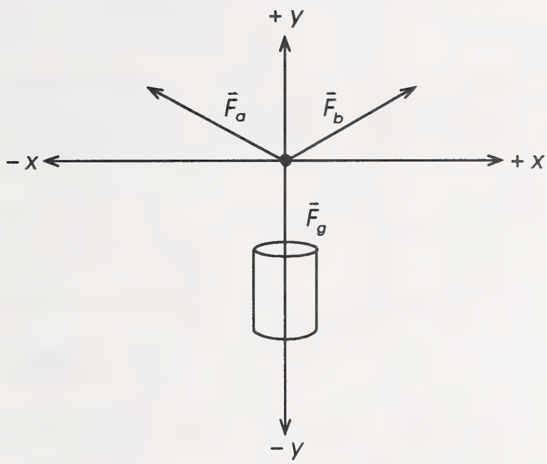
9. Record the values on the spring scales. Measure angles A, B, and C with the protractor and record them on a sketch of the apparatus. Call this Trial 1.

   Note: The sum of the angles should be close to 180°. Remeasure if necessary to get this value.

10. Move the tops of the spring scales so that they are 35 cm apart and repeat the procedure. Record the data on a sketch of the apparatus. Call this Trial 2.

Analysis

11. Draw a vector diagram for each trial that shows the three forces involved and all pertinent angles. Label the forces $\vec{F}_a$, $\vec{F}_b$, and $\vec{F}_g$. Your diagrams should look like the example shown at the top of the following page.



12. By resolving x- and y-components, find the resultant of Force A and Force B for Trial 1.

13. By resolving x- and y-components, find the resultant of Force A and Force B for Trial 2.

14. Compare the resultant force upward to the downward force supplied by the weight of the can for each trial. Are they similar?

15. When the scales were moved 35 cm apart, were the readings on the scales higher or lower?

Applications

16. If David is worried about the fishing line breaking, what might he do to ease the tension in the line?

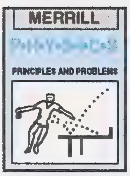
MERRILL P•H•Y•S•I•C•S PRINCIPLES AND PROBLEMS

Read pages 121 and 122 of the text to learn about equilibrium between forces. Study the Example Problem, but again note that the scalar versions of the equations should be used.

17. Define *equilibrium of forces.*

18. Define *equilibrant force.*

Check your answers by turning to the Appendix, Section 3: Activity 3.



19. Do Practice Problems 17 to 22 on page 123 of your textbook.

Check your answers by turning to pages 665 and 666 of your textbook.

Now that you've nearly reached the end of the module this is a good opportunity to review the main ideas.

20. Skim through the module booklet and identify all the new equations that have been introduced. Record these equations under appropriate headings on the sheet containing the main equations from Module 1.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Follow-up Activities

If you had difficulty understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. Explain the differences between vectors and scalars.

2. List four examples of vectors.

3. Find the magnitude and direction of these vectors.

   a. 3.0 N due east + 4.0 N due east

   b. 3.0 N due west + 4.0 N due east

   c. 3.0 N due east + 4.0 N due north

   d. 3.0 N due east + 4.0 N, E30°N

4. A river flows east at 8.0 m/s. David rows south across a 100-m stretch of river at 6.0 m/s.

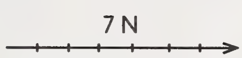
   a. Calculate the magnitude and direction of the boat's resultant velocity.

   b. How long does it take to cross the river?

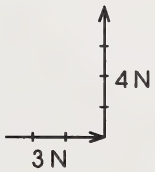
   c. Where will David dock on the other side?

5. Calculate the magnitude of the equilibrant of the following forces.

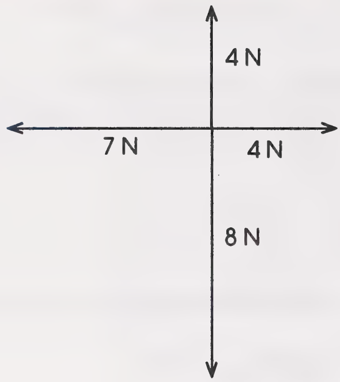
   a.



   b.



c.

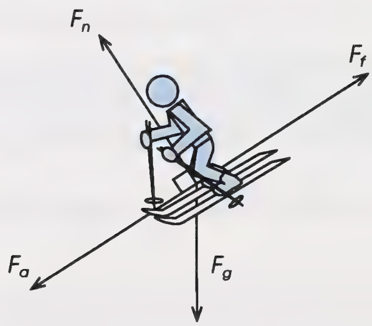


Enrichment

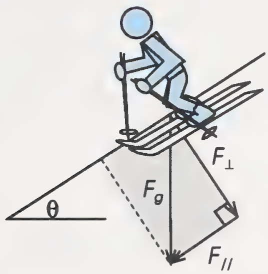
Do **one** of the following Enrichment activities.

1. Vectors Applied to Skiing

   A skier will accelerate faster down a steep slope than a small slope. Vector components can help you understand this. The force vector weight (F_g) acts straight down towards the centre of the earth, but the components of F_g can act in different directions.



The diagram shows the forces acting on the skier. The frictional force is in the opposite direction to the accelerating force. The normal force is always perpendicular to the ground.

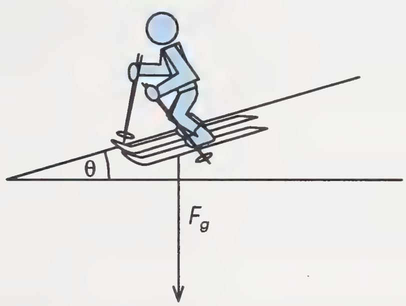


The weight vector can be resolved into two components – one parallel to the ground and one perpendicular to the ground.

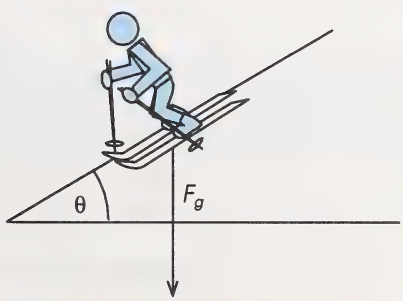
The parallel component makes the skier move, while the perpendicular component presses the skier against the snow. The longer the parallel vector, the faster the skier accelerates.

Draw in the perpendicular and parallel components of the weight on each of the following diagrams. Then shade in the rectangle.

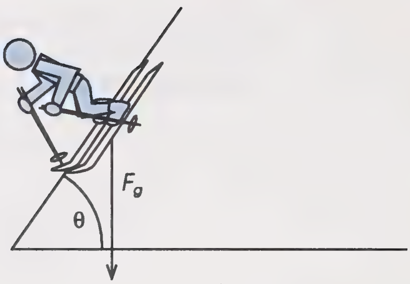
a.



b.

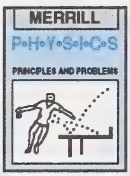


c.



d. At what angle will the parallel and perpendicular components of the weight be equal?

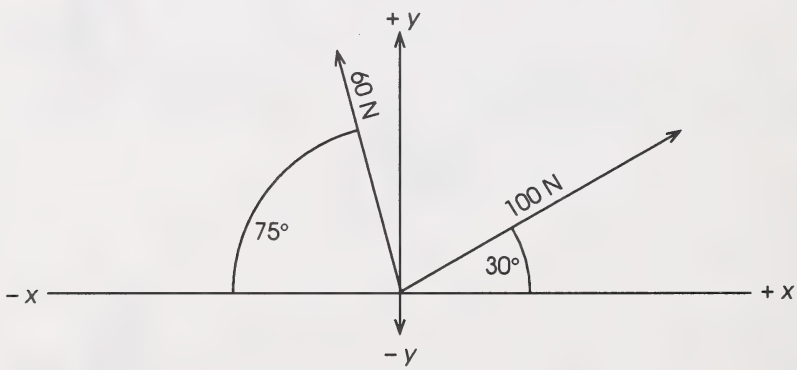
e. At what angle will the parallel component reach a maximum? At what angle will the parallel component reach a minimum?



Read pages 124, 125, and 126 in the textbook to learn some useful derivations of equations that you have already learned.

2. A Useful Short Cut

Vector rotation is a trick for saving time when adding vectors which are not on an *x*- or *y*-axis. For example, if you were given the following forces, and asked to find the resultant, rotating the vectors until one reaches the *x*-axis makes the calculations easier.

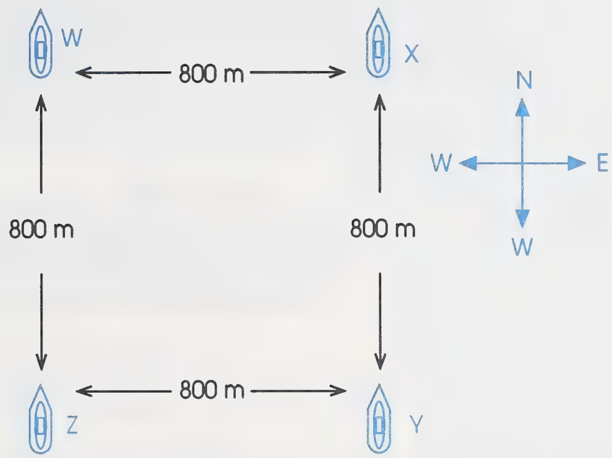


a. Rotate the 100-N vector 30° down to the *x* axis and rotate the 60-N vector 30° clockwise. Now find the resultant. Remember to rotate the resultant 30° counterclockwise to get the final answer.

b. Explain why this technique saves time and makes calculations easier.

3. Challenge Problems

   a. A convoy of four ships moves silently northward on a secret mission. They cannot communicate by radio or they will divulge their location.



   The convoy moves forward through still water at a rate of 5 m/s.

   The captain of Ship W needs to send a message to each of the other ships. He sends a small boat to deliver the message personally. The messenger boat travels from W to X to Y to Z and back to W at a uniform speed of 10 m/s. Calculate the minimum time necessary for the round trip, assuming the time spent at any one ship is very small.

   b. Three tugboats simultaneously pull on a barge. Tugboat A pulls with 432 kN, N30°E, Tugboat B pulls with 412 kN, W20°N, and Tugboat C pulls with 386 kN, S30°E. Calculate the magnitude and direction of the resultant force by resolving the vectors into their components.

   c. A boat in open water travels 4.8 m/s, E32°N while the ocean current is 2.0 m/s due east. Calculate the resultant velocity (magnitude and direction) of the boat using the laws of cosines and sines.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

In this section you have seen how vectors can be used to represent displacement, velocity, acceleration, and force. You've seen how two or more vectors can be added graphically or algebraically in one or two dimensions. Solving vector addition by resolving into vector components was emphasized. Through the camping trip activities, you have encountered some useful applications of vectors and will now begin to find your own applications as you begin to relate vectors to your everyday experiences.

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

MODULE SUMMARY

In this module you discovered Newton's three laws of motion and applied them to different situations such as automobile safety and elevators. You learned how to calculate values using vector addition, vector diagrams, and vector components.

You now have a firm foundation in the basics of motion, forces, and vectors. In the next module you will combine these concepts to deal with projectile motion, circular motion, and gravitation.

Appendix

Glossary

Activities

Extra Help

Enrichment

Glossary

coefficient of friction – the ratio of the frictional force to the normal force for two surfaces in contact. The coefficient of friction depends on the nature of the two surfaces.

dynamics – the study of why objects move

electromagnetic force – an attractive or repulsive force that exists between charged objects

equilibrant – the force that, when applied to the other forces, will produce equilibrium. It is equal and opposite to the resultant of the other forces.

equilibrium – Forces are in equilibrium when the net sum of all the forces acting is zero.

friction – the force that opposes the motion between two surfaces

gravitational force – an attractive force that exists between all objects due to their mass

impulse – the product of a force and the time interval through which it acts

$$\text{Impulse} = \vec{F}(\Delta t)$$

inertia – the tendency of an object not to change its motion

inertial mass – Using Newton's second law, mass can be defined in terms of the force needed to cause an acceleration.

$$m = \frac{F}{a}$$

kinematics – the study of how objects move

manipulated variable – the variable that is altered

mass – a measure of the quantity of matter a body contains

momentum – the product of the mass and the velocity of an object $(\vec{p} = m\vec{v})$

net force – the force that remains unbalanced when all the forces on an object are totalled. This force is described by $\vec{F}_{net} = m\vec{a}$.

Newton's first law – If no external net forces act on an object, the object will maintain its velocity.

Newton's second law – $\vec{F}_{net} = m\vec{a}$

Newton's third law – For every action there is an equal and opposite reaction.

normal force – the force that pushes two surfaces together. This force acts perpendicular to the surface.

responding variable – the variable that is affected by the change in the manipulated variable

resultant – the single vector that could represent the sum of several vectors

sliding friction – the force that opposes the motion between two surfaces

static friction – the force that opposes the start of motion between two surfaces

strong nuclear force – holds the particles of the nucleus together

terminal velocity – the maximum velocity of a falling object. At this velocity the drag force balances the force of gravity, producing uniform motion.

vector – a measured quantity that has both magnitude (size) and direction

volume – the three-dimensional space which is occupied by an object

weak nuclear force – governs radioactive decay

weight – the force of gravity that acts on an object

$$\vec{F}_g = m\vec{g}$$

Suggested Answers

Section 1: Activity 1

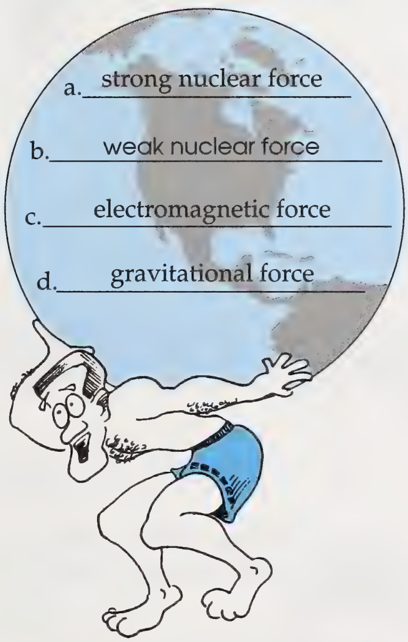
1. Kinematics is the study of how objects move and dynamics is the study of why they move.

2. A force is a push or pull.

3. The gravitational force of the moon is responsible for the tides.

4. The strong nuclear force and the weak nuclear force act over short distances.

5.



6. Newton's first law is consistent with Galileo's explanation of motion.

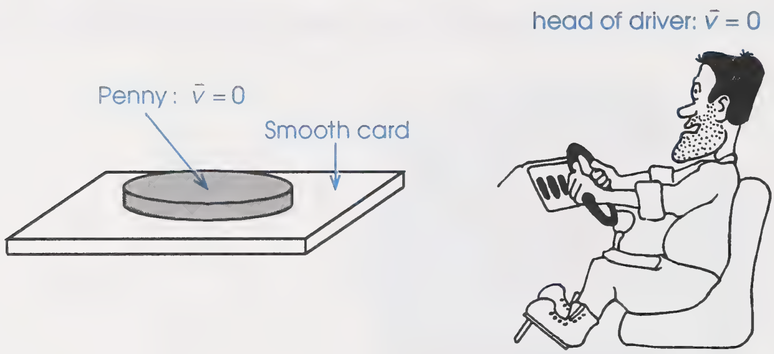
7. The initial velocity of the penny was zero. Since the card was smooth, it was unable to put a significant net force on the penny. According to Newton's first law, the penny remained at rest because there was no force to change its velocity.

8. The card had to be smooth so that no net force would be applied to the penny. If a net force was applied, the penny would change its velocity and move with the card.

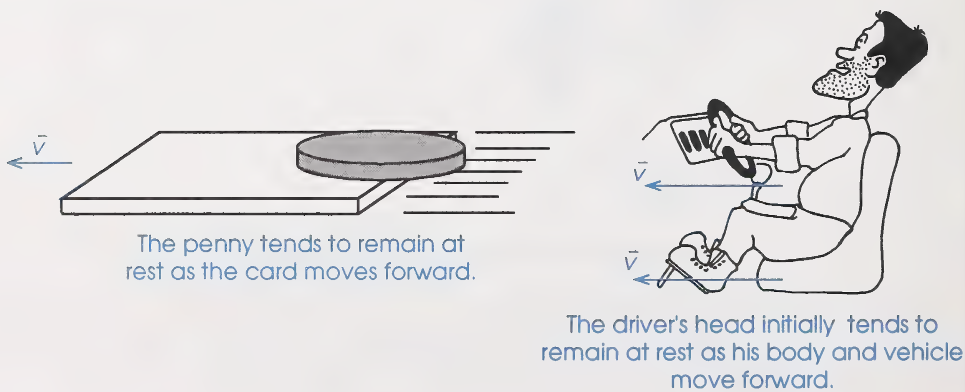
9. The key to the magician's trick is to use a very smooth material for the tablecloth and to pull the cloth out in one continuous rapid motion. This will ensure that the items on the table will not experience a net force. It also helps if the items on the table have more mass than usual. You will learn more about this in Activity 4.

10. Textbook question 2. a.:

    This situation is very similar to the penny and card trick, as shown in the following diagram.



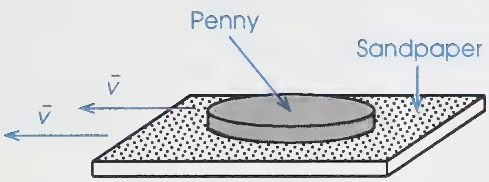
The behavior of the driver's head is similar to that of the penny. When the car is pushed forward by the rear-end collision, the driver's head tends to remain at rest, according to Newton's first law.

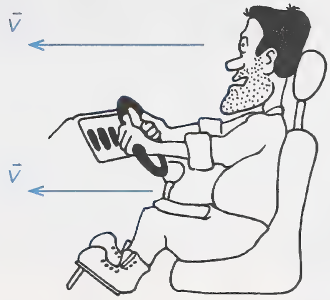


There is one important difference between the penny and the head of the driver. The penny is not attached to the card, but the driver's head is attached to his body! The neck undergoes incredible strain as the body moves out from underneath it and as it whips the head forward to catch up with the driver's body and the car.

Textbook question 2. b.:

A headrest can reduce whiplash in rear-end collisions by forcing the driver's head forward as the car moves forward. This allows an unbalanced or net force to act on the driver's head so that the head is not permitted to remain at rest. The effect is similar to the penny trick done with sandpaper instead of a smooth card.





The headrest must be properly adjusted to supply the whole head with a net force.

11. If you are travelling at 60 km/h and hit a large tree, Newton's first law states that, in the absence of a net force, you will tend to maintain your velocity. This means that the car will maintain its velocity of 60 km/h until it is stopped by the tree. Meanwhile, you will still be moving at 60 km/h until you are stopped. If you are wearing a seatbelt, the seatbelt will spread the force over your torso and slow you down with the car. If you are not wearing a seatbelt, you will maintain your velocity of 60 km/h until your head hits the steering wheel or the windshield.

Section 1: Activity 2

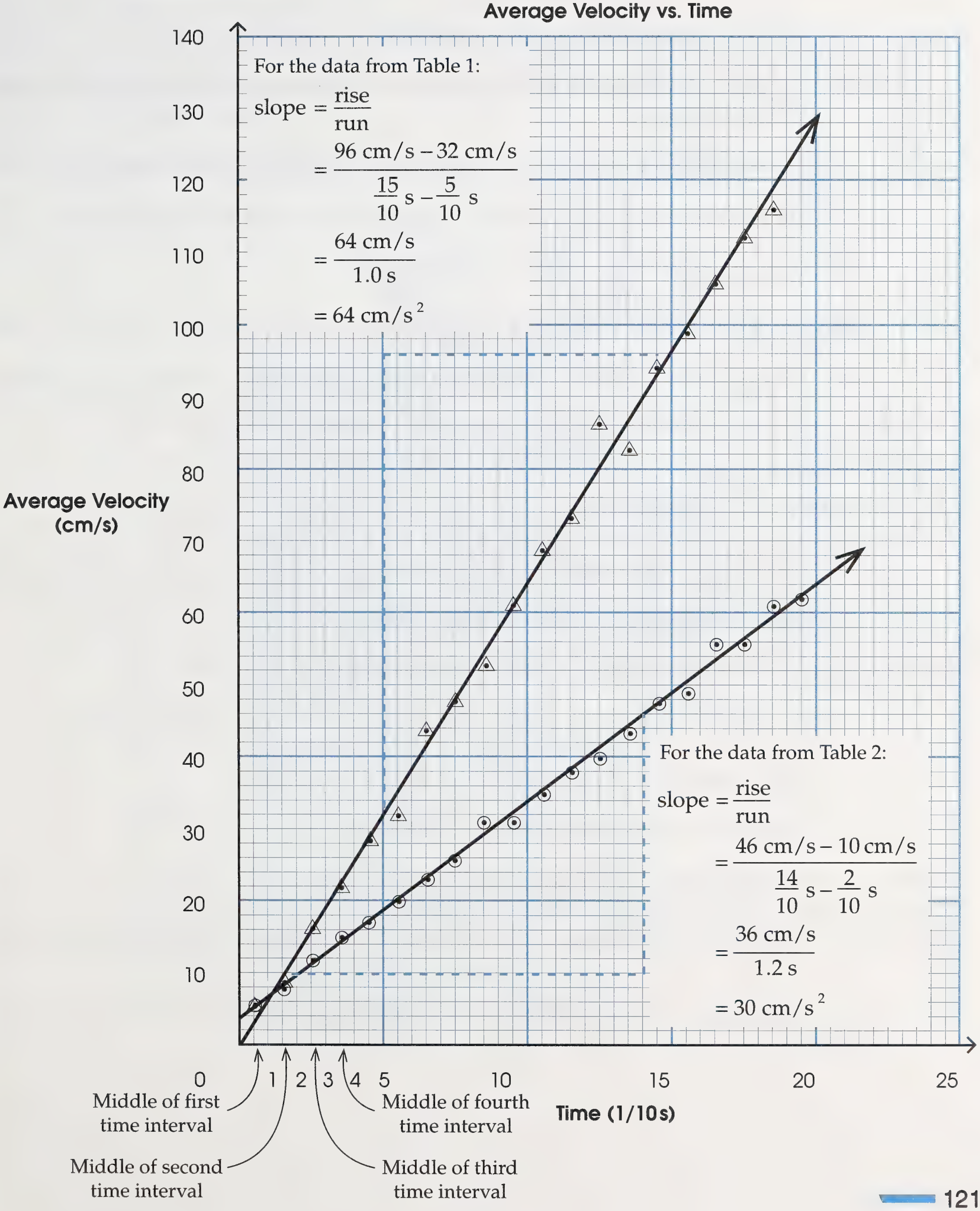
1. Answers to this question will vary, depending on the details of your particular setup. Refer the answers given for questions 2 through 5.

2.
3.
4.
5.

$\left.\right\}$ Sample answers to these questions are provided on the data chart that follows. The chart is based upon the prepared ticker tape data provided for Part B of the investigation.

Table for Ticker Tape Data – Part B							
TABLE 1				TABLE 2			
Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)	Time (1/10 s)	Position (cm)	Displacement from Previous Dot (cm)	Average Velocity in the Interval (cm/s)
0	0	–	–	0	0	–	–
1	0.6	0.6	6.0	1	0.6	0.6	6.0
2	1.5	0.9	9.0	2	1.4	0.8	8.0
3	3.1	1.6	16	3	2.6	1.2	12
4	5.3	2.2	22	4	4.1	1.5	15
5	8.2	2.9	29	5	5.8	1.7	17
6	11.4	3.2	32	6	7.8	2.0	20
7	15.8	4.4	44	7	10.1	2.3	23
8	20.6	4.8	48	8	12.7	2.6	26
9	25.9	5.3	53	9	15.8	3.1	31
10	32.0	6.1	61	10	18.9	3.1	31
11	38.6	6.9	69	11	22.4	3.5	35
12	45.9	7.3	73	12	26.2	3.8	38
13	54.6	8.7	87	13	30.2	4.0	40
14	62.9	8.3	83	14	34.5	4.3	43
15	72.2	9.3	93	15	39.3	4.8	48
16	82.1	9.9	99	16	44.2	4.9	49
17	92.7	10.6	106	17	49.8	5.6	56
18	103.9	11.2	112	18	55.4	5.6	56
19	115.5	11.6	116	19	61.5	6.1	61
20	–	–	–	20	67.7	6.2	62

6. The graph presented here is a sample based on the ticker tape data provided in Part B of the investigation. Note that the middle of the time interval has been indicated for the first four points.



7. The slope of the best fit line has units of cm/s^2.

8. The slopes of the lines represent the acceleration.

9. Doubling the mass decreases the acceleration by approximately half.

10. If the spark timer was set to 20 sparks per second, the time between sparks would be 1/20 s or 0.050 s.

11. Tripling the mass would cause the acceleration to drop to a third of its original value.

12. The position-time graph would be a parabola, since this is accelerated motion.

13. Mass and acceleration are inversely related.

14. There is an inverse relationship between sparks per second and time between sparks.

15. The snowmobile with the greater mass would trail behind the lighter one if they both experience the same net force. The investigation suggested that the smaller the mass, the greater the acceleration an object will experience, for a given force.

Section 1: Activity 3

1. Experience would suggest that the cart undergoing the larger force would have a larger acceleration. Since both carts start from rest, this implies that the cart experiencing the larger force would also reach a higher velocity.

2. Force and acceleration are directly proportional to each other.

3. Force is the manipulated variable and acceleration is the responding variable.

4. The standard unit of mass in SI metric units is the kilogram.

5. The standard unit of acceleration is m/s^2.

6. The unit of force is called the newton.

7. The newton is defined as the force that causes a 1-kg mass to accelerate at the rate of $1\ m/s^2$.

8. The answers to these problems can be found on page 662 of your textbook.

Section 1: Activity 4

1. $\vec{F}_{hand \rightarrow ball} = -\vec{F}_{ball \rightarrow hand}$ $\qquad$ $\vec{F}_{Earth \rightarrow ball} = -\vec{F}_{ball \rightarrow Earth}$

2. The words describing the forces are in the reverse order on opposite sides of the equation. A negative sign is also present on one side of the equation to indicate the opposite direction.

   Reconsider the answers to question 1.

$$\vec{F}_{hand \rightarrow ball} \quad = \quad -\vec{F}_{ball \rightarrow hand}$$

   Reverse the
   order of the words.

3. a. rocket propulsion: Newton's third law applies here. The action of the exhaust causes the reaction of the rocket moving forward.

   b. whiplash: Newton's first law applies. You are stopped at the lights and your car gets hit from behind. Your head is an object at rest, so it tends to remain at rest. It stays behind while the car moves the rest of your body forward.

4. Newton's second law explains the difference. The acceleration of the shot is proportional to the force behind it. The larger the shotputter, the greater the force on the shot, and the greater the shot's acceleration. The acceleration of the sprinter is inversely proportional to the sprinter's mass.

5. Sandpaper on sandpaper would have larger crevices that would become entwined.

6. Increasing the force between the surfaces would increase the frictional force by squeezing the high points deeper into the crevices.

7. A car has a large mass and a lot of inertia. It will have a strong tendency to remain at rest once at rest and a strong tendency to remain in motion once in motion. This makes it hard to get it rolling but easy to keep it going. This is in accordance with Newton's first law of motion.

8. Newton's first law is sometimes called the law of inertia.

9. You could distinguish between the packages by shaking them. The television has more mass (more inertia) and would be harder to move back and forth. It would provide a greater resistance to a change in its motion. The box of popcorn has less mass (less inertia) and would be easier to move back and forth.

10. The Example Problem on page 94 of the textbook gives the impression that the vector approach will be used because of the use of the equation $\vec{W} = m\vec{g}$. However, the value used for $\vec{g}$ is a scalar and the answer is a scalar.

    If a consistent vector approach is used, the Example Problem should look like this.

    $m = 2.26\ \text{kg}$
    $\vec{g} = -9.80\ \text{m/s}^2$
    $\vec{F}_g = ?$

    $$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (2.26\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -22.148\ \text{N}\\ &= -22.1\ \text{N}\end{aligned}$$

    The weight of the bag is 22.1 N down.

11. A vector approach was used for question 5. A scalar approach would be fine since neither method was specified.

    Textbook question 5. a.:

    $m = 0.113\ \text{kg}$
    $\vec{g} = -9.80\ \text{m/s}^2$
    $\vec{F}_g = ?$

    $$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (0.113\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -1.107\ \text{N}\\ &= -1.11\ \text{N}\end{aligned}$$

    Textbook question 5. b.:

    $m = 108\ \text{kg}$
    $\vec{g} = -9.80\ \text{m/s}^2$
    $\vec{F}_g = ?$

    $$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (108\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -1058.4\ \text{N}\\ &= -1.06\times 10^3\ \text{N}\end{aligned}$$

Textbook question 5. c.:

$m = 870 \text{ kg}$
$\vec{g} = -9.80 \text{ m/s}^2$
$\vec{F}_g = ?$

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (870 \text{ kg})(-9.80 \text{ m/s}^2)\\ &= -8526 \text{ N}\\ &= -8.53 \times 10^3 \text{ N}\end{aligned}$$

The weights are all listed as scalars for question 6. This seems to imply a scalar approach, but a vector approach would also give correct answers.

Textbook question 6. a.:

$F_g = 98 \text{ N}$
$g = 9.80 \text{ m/s}^2$
$m = ?$

$$\begin{aligned}F_g &= mg\\ m &= \frac{F_g}{g}\\ &= \frac{98 \text{ N}}{9.80 \text{ m/s}^2}\\ &= 10 \text{ kg}\\ &= 1.0 \times 10^1 \text{ kg}\end{aligned}$$

Textbook question 6. b.:

$F_g = 80 \text{ N}$
$g = 9.80 \text{ m/s}^2$
$m = ?$

$$\begin{aligned}F_g &= mg\\ m &= \frac{F_g}{g}\\ &= \frac{80 \text{ N}}{9.80 \text{ m/s}^2}\\ &= 8.2 \text{ kg}\end{aligned}$$

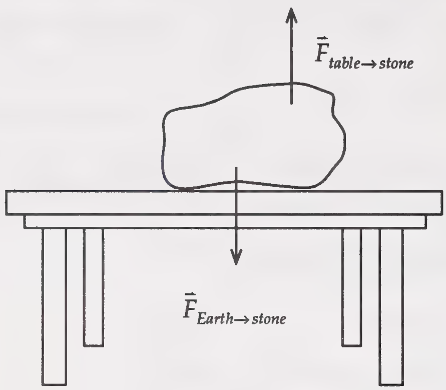
Textbook question 6. c.:

$F_g = 0.98 \text{ N}$
$g = 9.80 \text{ m/s}^2$
$m = ?$

$$\begin{aligned}F_g &= mg\\ m &= \frac{F_g}{g}\\ &= \frac{0.98 \text{ N}}{9.80 \text{ m/s}^2}\\ &= 0.10 \text{ kg}\\ &= 1.0 \times 10^{-1} \text{ kg}\end{aligned}$$

Textbook question 7:

This question is best answered with a labelled diagram.



As shown, the force of the table on the stone is 20 N directed upwards.

For question 8, vector arrows are placed above g in the textbook (although the accelerations are not printed as negatives). This implies a vector approach. Again, the scalar approach would also be considered correct since neither method was specified.

Textbook question 8. a.:

$m = 75\text{ kg}$

$\vec{g} = -9.80\text{ m/s}^2$

$\vec{F}_g = ?$

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (75\text{ kg})(-9.80\text{ m/s}^2)\\ &= -735\text{ N}\\ &= -7.4 \times 10^2\text{ N}\end{aligned}$$

Textbook question 8. b.:

$m = 75\text{ kg}$

$\vec{g} = -3.8\text{ m/s}^2$

$\vec{F}_g = ?$

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (75\text{ kg})(-3.8\text{ m/s}^2)\\ &= -285\text{ N}\\ &= -2.9 \times 10^2\text{ N}\end{aligned}$$

Textbook question 8. c.:

$$m = 75\ \text{kg}$$
$$\vec{F}_g = -683\ \text{N}$$
$$\vec{g} = ?$$

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ \vec{g} &= \frac{\vec{F}_g}{m}\\ &= \frac{-683\ \text{N}}{75\ \text{kg}}\\ &= -9.10\overline{6}\ \text{m/s}^2\\ &= -9.1\ \text{m/s}^2\end{aligned}$$

Section 1: Follow-up Activities

Extra Help

1. Although the sample sentences will vary, the definitions should be consistent.

Definitions		
Term	**Definition**	**The Term in a Complete Sentence**
Friction	Friction is the force that opposes the motion between two surfaces.	By lubricating two surfaces with oil, you can reduce the friction between them.
Inertia	Inertia is the tendency of an object to remain at rest once at rest or to remain in motion once in motion.	The inertia of the oil tanker is so tremendous that tugboats are used to maneuver it.
Mass	Mass is a measure of the quantity of matter an object contains.	The mass of some black holes may be larger than thousands of stars.

Definitions		
Term	**Definition**	**The Term in a Complete Sentence**
Weight	Weight is the force of gravity on an object.	The sumo wrestler named Meat Bomb has a weight of over 600 lbs.
Force	A force is a push or a pull on something. Force is measured in newtons.	The forces exerted on your head as you fall off a bicycle are so large that permanent damage can result. This is why you should always wear a helmet.

2. a. Newton's first law applies to this situation. Since the car travels with a constant velocity, there is no net force on the car. The force provided by the engine is completely cancelled by the forces of air resistance and friction.

   b. Newton's third law applies to this situation. It is the reaction force of the water back on the paddle that causes the canoe to move through the water.

$$\vec{F}_{paddle \rightarrow water} = -\vec{F}_{water \rightarrow paddle}$$

   c. Newton's first law applies to this situation. Prior to hitting the brakes, the passengers were in motion. When the brakes are hit, the bus slows down, but the passengers tend to maintain their velocity.

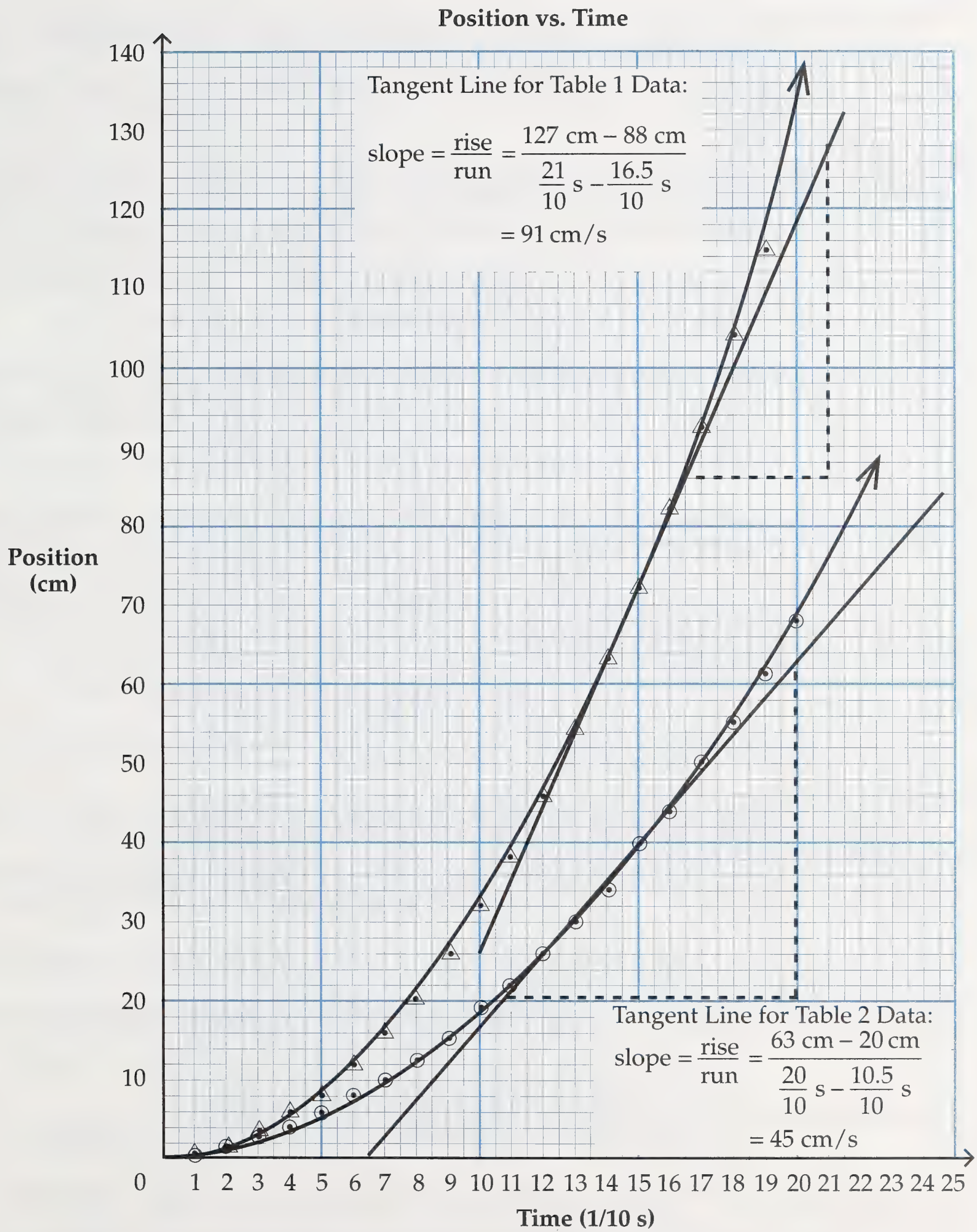
   d. Newton's second law applies to this situation. An increase in speed implies an acceleration. For the car to accelerate, a net force is required to act on the car. The engine must be supplying a larger force than air resistance and friction.

Enrichment

1. a. See the graph that follows question 1. c.

   b. See the graph that follows question 1. c.

   c. See the following graph.



Position vs. Time
Tangent Line for Table 1 Data:
slope = rise/run = (127 cm – 88 cm) / (21/10 s – 16.5/10 s)
= 91 cm/s
Tangent Line for Table 2 Data:
slope = rise/run = (63 cm – 20 cm) / (20/10 s – 10.5/10 s)
= 45 cm/s
Position (cm)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Time (1/10 s)

d. The slope of the tangent line represents the instantaneous velocity.

2. Answers will vary, depending on the resources that you use. Sample answers are provided.

   a. Isaac Newton was born in 1643 (the year Galileo died). He never married or had children. He attended Cambridge University in England. When the plague hit London in 1666, he moved to his mother's farm to escape danger. It was there that he had time to incubate many of his important scientific and mathematical contributions. He calculated the day of creation to be 3500 BC and tried to find a way to make gold. He died in England in 1727.

   b. Newton developed the binomial theorem and calculus. Newton also did extensive work in the field of optics and was famous for the rainbow of colours when white light was split by a prism. He built the first reflecting telescope. He developed the three laws of motion and the universal law of gravity.

3. The answers to this very creative effort will vary greatly from group to group. However, since the bottom line is to communicate the main idea behind each of Newton's three laws of motion, each commercial should clearly convey the basic concepts to the viewer. A good blueprint of what each commercial should convey can be found at the beginning of the Extra Help section, where Newton's Laws are summarized.

Section 2: Activity 1

1. Newton's first law: Objects tend to have a constant velocity unless acted on by a force.

   Newton's second law: Newton's second law states that objects will accelerate in the direction of an unbalanced force such that $F = ma$.

   Newton's third law: For every action force there is an equal but opposite reaction force.

2. Three examples that illustrate Newton's first law would include the following:

   - A rocket will not move unless its engines exert a force.
   - A car will not stop unless the brakes exert a force.
   - A comet moving through space will continue forever if unimpeded.

3. a. As the force on an object increases, the acceleration tends to **increase**.

   b. As the mass of an object increases, the acceleration tends to **decrease**.

4. Newton's third law: When two objects interact, they exert forces on each other which are equal in strength and opposite in direction.

5. Textbook question 3:

   To start a bicycle from rest to some constant velocity requires a net force to accelerate the bicycle. The size of the net force will depend on the mass of the rider and the amount of acceleration, as given by Newton's second law ($\vec{F}_{net} = m\vec{a}$).

   Keeping a bicycle moving at a constant velocity requires that all the forces on the bicycle be balanced, according to Newton's first law. The force that is applied through the pedals is balanced by the forces of air resistance and friction, resulting in no net force. Since these resistant forces are so small, the force on the pedals would also be small.

   Textbook question 4:

   It's true that Newton's third law does predict the following action-reaction pair:

$$\vec{F}_{Earth \rightarrow rock} = -\vec{F}_{rock \rightarrow Earth}$$

   However, the mass of Earth is so overwhelmingly large compared to this force that the resulting acceleration is undetectable because it is so tiny.

   Textbook question 5:

   This is a trick question. The mass of an object does not change from place to place. If the textbook has a mass of 3.0 kg on Earth, it will have the same mass on Jupiter. Weight, which is the force of gravity, does change from place to place. The textbooks would have a weight ten times greater on Jupiter, but this is not what the question asked.

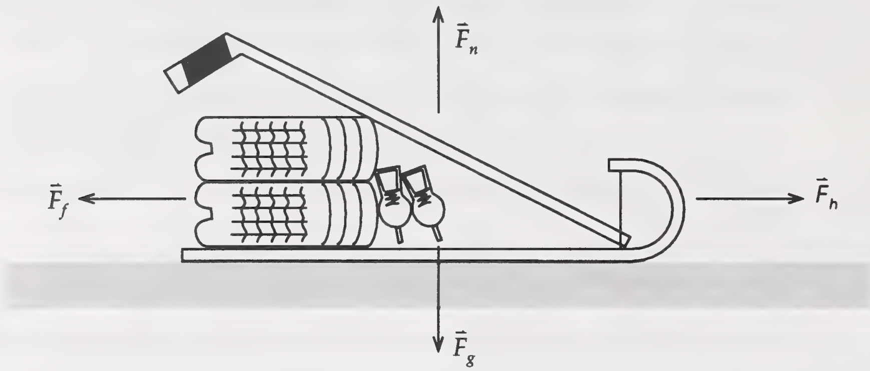
6. Without the force of friction, Marc would not be able to push on the ground with his boot. The situation would be similar to walking on very slippery ice. Since he could not push on the ground, the ground would be unable to supply the reaction force for him to move forward.

7. The toboggan's smooth bottom reduces friction so it can move easily over the ground with little resistance.

8. Moving a loaded toboggan that is at rest requires a large force. The force that opposes the start of the motion is called the force of static friction. Once the toboggan is moving, the force required to maintain the motion is less. This is because the force that opposes the motion (called the force of sliding friction) is less than the force of static friction.

9. If Marc is pulling the toboggan along at a constant speed, the forces on the toboggan are balanced, according to Newton's first law. This means that the force that he applies is equal to the force of friction. The force of friction could be measured by seeing how many newtons it took to pull the toboggan at a constant speed. This could be measured with a spring scale.

10.



11. $$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (12.5\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -122.5\ \text{N}\\ &= -1.23\times10^2\ \text{N}\end{aligned}$$

12. The normal force is the force that pushes two surfaces together.

13. The normal force balances the force of gravity. These forces cancel each other out, giving a net vertical force of zero. This means that the normal force must be 1.23×10^2 N directed straight up.

14. The coefficient of friction is a constant that describes the amount of friction between two surfaces. If depends on the nature of the two surfaces. The coefficient of friction can be calculated according to the equation $\mu = F_f / F_n$. No vector signs should be on the forces.

15. The coefficient of friction for the toboggan would be determined by the smoothness of the bottom of the toboggan and by the stickiness and texture of the snow.

16.

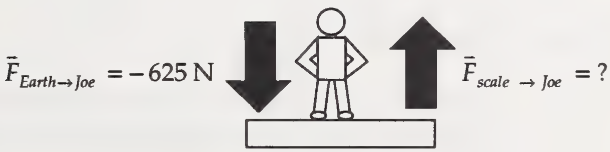
$$F_f = \mu F_n$$

This is determined by the interaction between the snow and the bottom of the toboggan. If the toboggan slides easily over the snow, the force of friction will be reduced.

This is determined by the weight of the toboggan. The greater the load, the larger the normal force and the larger the force of friction.

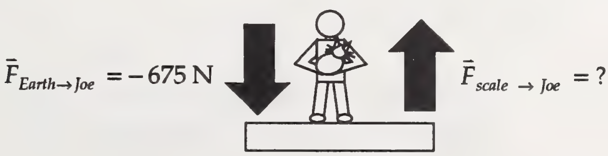
17. Marc could reduce the force of friction by lightening the load on the toboggan and making sure that the bottom of the toboggan is smooth.

18. Textbook question 9. a.:



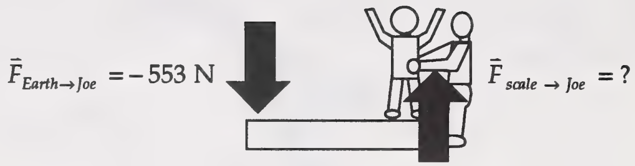
Since Joe is not accelerating, there is no net force. The force exerted by the scale is a balancing force to cancel out the weight on the scale. Therefore, the force of the scale on Joe is 625 N directed up.

Textbook question 9. b.:



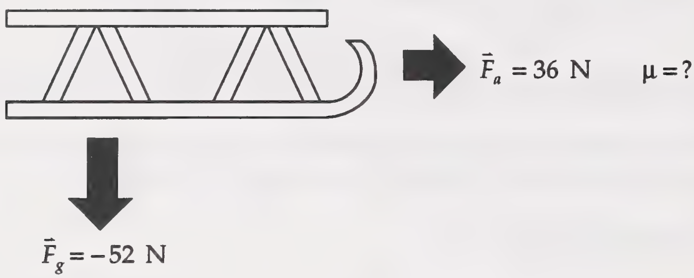
The force of the scale on Joe should be 675 N directed up.

Textbook question 9. c.:



The force of the scale should be 553 N directed up.

19. Textbook question 10. a.:



Step 1: Find the normal force.

Since the sled is not accelerating up or down, the weight must be balanced by some other force (the normal force), according to Newton's second law.

$$F_n = 52\ \text{N}$$

Since the coefficient of friction equation should not use vectors, the normal force is written as a scalar.

Step 2: Find the force of friction.

Since the sled is pulled along with a constant speed, all the forces must balance, according to Newton's first law. In other words, the applied force must be completely cancelled by the force of friction. This means that the force of friction is 36 N directed opposite to the applied force.

$$F_f = 36\ \text{N}$$

Again, note that the force of friction is not expressed as a vector.

Step 3: Calculate the coefficient of friction.

$$\mu = \frac{F_f}{F_n} = \frac{36\ \text{N}}{52\ \text{N}} = 0.69$$

Textbook question 10. b.:

Step 1: Find the normal force.

The normal force is a balancing force which is equal and opposite to the total weight.

$$\begin{aligned}\text{total weight} &= 52\ \text{N} + 650\ \text{N}\\ &= 702\ \text{N}\end{aligned}$$

$$F_n = 702\ \text{N}$$

Step 2: Find the force of friction.

$$\begin{aligned}\mu &= 0.12 \\ F_n &= 702\ \text{N} \\ F_f &= ?\end{aligned} \qquad \begin{aligned}F_f &= \mu F_n \\ &= (0.12)(702\ \text{N}) \\ &= 84\ \text{N}\end{aligned}$$

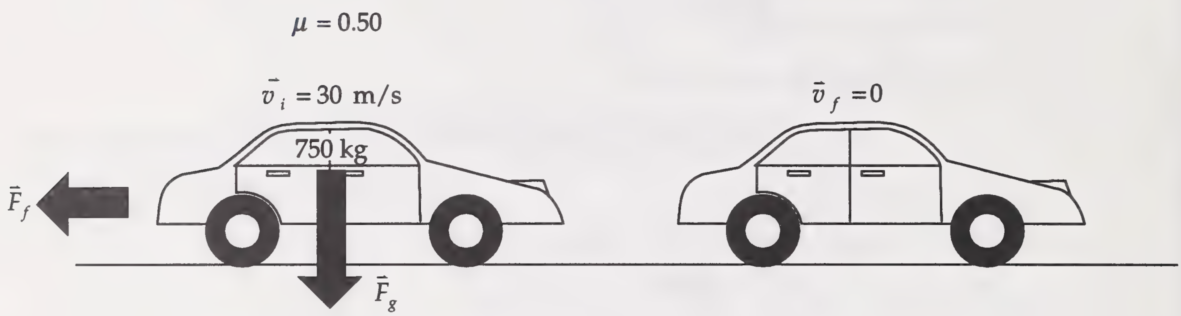
Step 3: Find the applied force.

Since the sled runs at a constant speed, the forces balance, according to Newton's first law. Therefore, the force of friction is cancelled by the applied force, which must also be 84 N.

$$F_a = 84\ \text{N}$$

20. Textbook question 11. a.:

Since this involves the coefficient of friction, all force calculations will be non-vector.



Step 1: Find the weight of the car.

$m = 750\ \text{kg}$
$g = 9.80\ \text{m/s}^2$
$F_g = ?$

$$\begin{aligned} F_g &= mg \\ &= (750\ \text{kg})(9.80\ \text{m/s}^2) \\ &= 7350\ \text{N} \\ &= 7.35 \times 10^3\ \text{N} \end{aligned}$$

Step 2: Find the normal force. The normal force balances the weight of the car.

$$F_n = 7.35 \times 10^3\ \text{N}$$

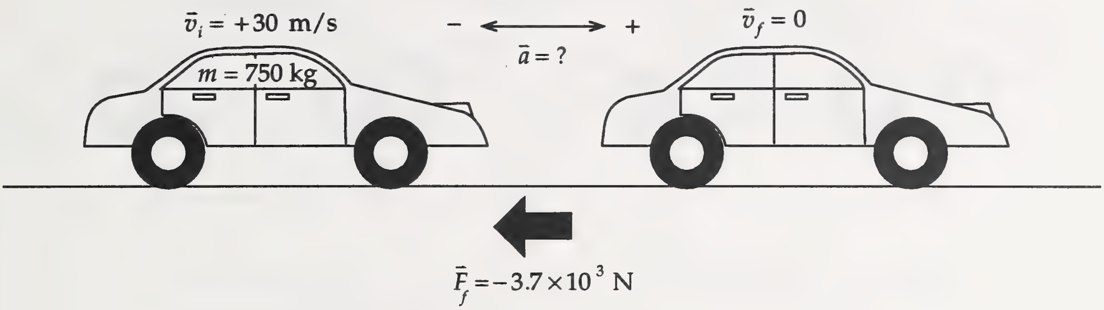
Step 3: Find the force of friction.

$$\begin{aligned} F_f &= \mu F_n \\ &= (0.50)(7.35 \times 10^3\ \text{N}) \\ &= 3675\ \text{N} \\ &= 3.7 \times 10^3\ \text{N} \end{aligned}$$

Note that all the equations for 11. a. were treated as scalars.

Textbook question 11. b.:

Since the direction is asked for, this problem will involve vector equations.



The original direction of the car is considered to be positive. Since the force of friction slows it down, it acts in the opposite, or negative, direction.

Step 1: Find the net force.

Since the force of friction is the only unbalanced force acting, it is the net force.

$$\vec{F}_{net} = \vec{F}_f = -3.675 \times 10^3 \text{ N}$$

Step 2: Find the acceleration.

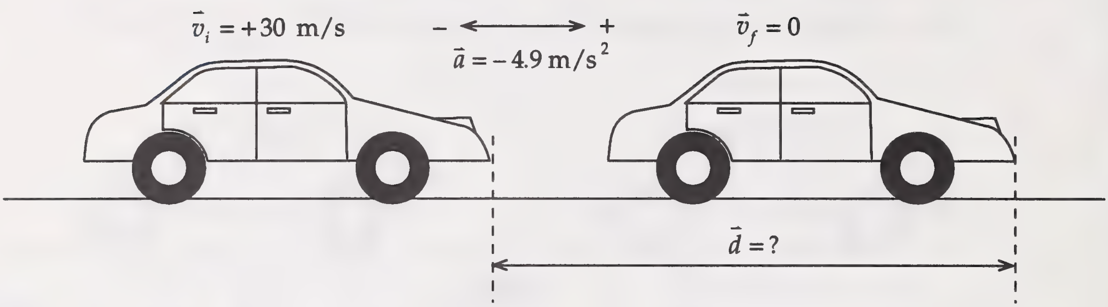
$m = 750$ kg
$\vec{F}_{net} = -3.675 \times 10^3$ N
$\vec{a} = ?$

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{-3.675 \times 10^3 \text{ N}}{750 \text{ kg}} = -4.9 \text{ m/s}^2$$

The car accelerates at 4.9 m/s^2 in the opposite direction to its original motion.

Textbook question 11. c.:



$\vec{v}_i = +30 \text{ m/s}$

$\vec{v}_f = 0$

$\vec{a} = -4.9 \text{ m/s}^2$

$\vec{d} = ?$

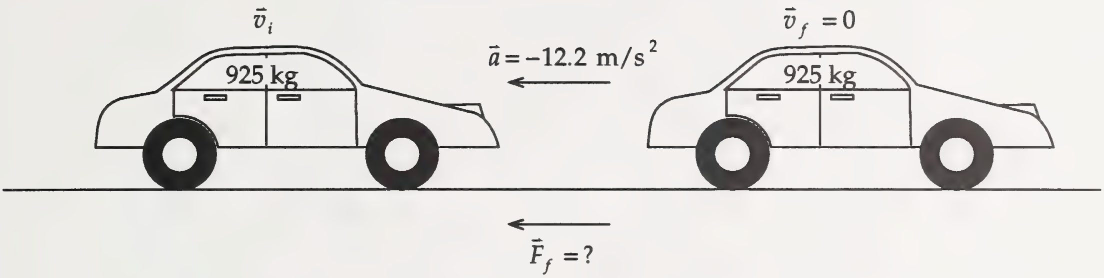
$$\begin{aligned}
v_f^2 &= v_i^2 + 2ad \\
v_f^2 - v_i^2 &= 2ad \\
d &= \frac{v_f^2 - v_i^2}{2a} \\
&= \frac{(0)^2 - (30 \text{ m/s})^2}{2(-4.9 \text{ m/s}^2)} \\
&= \frac{-900 \text{ m}^2/\text{s}^2}{-9.8 \text{ m/s}^2} \\
&= 92 \text{ m}
\end{aligned}$$

Note that the vector notation is deleted from this particular equation.

21. Textbook question 12:

If the coefficient of friction was larger, the force of friction would be larger because of the relationship between the coefficient of friction and the force of friction. When the coefficient of friction is increased, the force of friction is increased. A larger force of friction would mean a larger value for the deceleration that stops the car and a shorter stopping distance. Avoiding a skid means that the car would come to a stop sooner. This is why drivers are encouraged to pump their brakes rather than jamming them tight when stopping in slippery conditions.

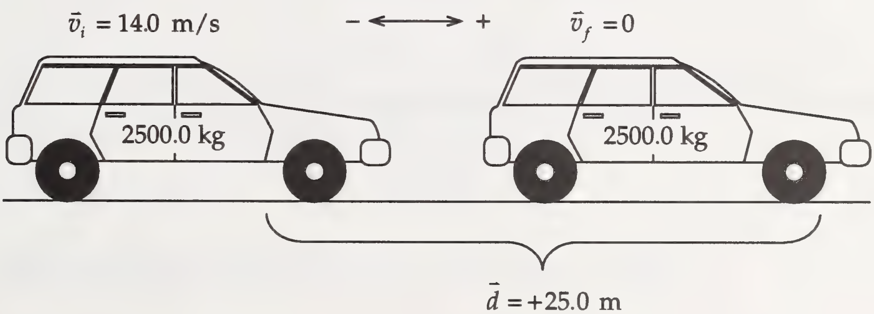
22. Textbook question 14:



The frictional force provides the net force and the negative acceleration (deceleration) for stopping.

$$\begin{aligned}\vec{F}_f = \vec{F}_{net} &= m\vec{a}\\ &= (925\ \text{kg})(-12.2\ \text{m/s}^2)\\ &= -11\,285\ \text{N}\\ &= -1.13 \times 10^4\ \text{N}\end{aligned}$$

Textbook question 16:



Step 1: Find the acceleration.

$$v_f^2 - v_i^2 = 2ad$$

$$a = \frac{v_f^2 - v_i^2}{2d}$$

$$= \frac{-v_i^2}{2d}$$

$$= \frac{-(14.0 \text{ m/s})^2}{2(25.0 \text{ m})}$$

$$= -3.92 \text{ m/s}^2$$

Step 2: Find the force of friction. The force of friction causes the deceleration.

$$\vec{F}_f = \vec{F}_{net} = m\vec{a}$$

$$= (2500.0 \text{ kg})(-3.92 \text{ m/s}^2)$$

$$= -9800 \text{ N}$$

$$= -9.80 \times 10^3 \text{ N}$$

Step 3: Find the weight of the car.

$$F_g = mg$$

$$= (2500.0 \text{ kg})(9.80 \text{ m/s}^2)$$

$$= 24\,500 \text{ N}$$

$$= 2.45 \times 10^4 \text{ N}$$

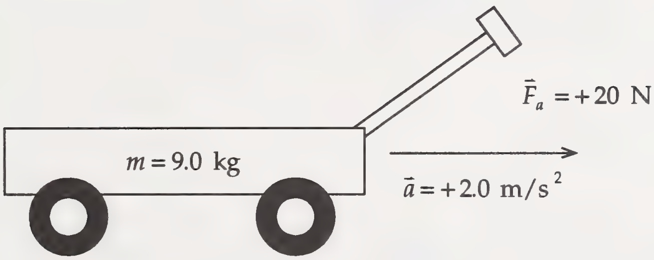
Step 4: Find the normal force. The normal force balances the weight of the car.

$$F_n = 2.45 \times 10^4 \text{ N}$$

Step 5: Find the coefficient of friction. Note that vector notation is dropped here.

$$\mu = \frac{F_f}{F_n}$$
$$= \frac{9.80 \times 10^3 \text{ N}}{2.45 \times 10^4 \text{ N}}$$
$$= 0.400$$

23. Textbook question 8. a.:



$$\vec{F}_{net} = m\vec{a}$$
$$= (9.0 \text{ kg})(2.0 \text{ m/s}^2)$$
$$= 18.0 \text{ N}$$

If 20.0 N is being applied, but only 18.0 N is needed to provide the acceleration, the force of friction must be -2.0 N. Since the force of friction opposes the direction of motion, it is 2.0 N in the opposite direction.

Textbook question 8. b.:

Step 1: Find the weight of the cart.

$$F_g = mg$$
$$= (9.0 \text{ kg})(9.80 \text{ m/s}^2)$$
$$= 88.2 \text{ N}$$
$$= 8.8 \times 10^1 \text{ N}$$

Step 2: Find the normal force. The normal force balances the weight of the car.

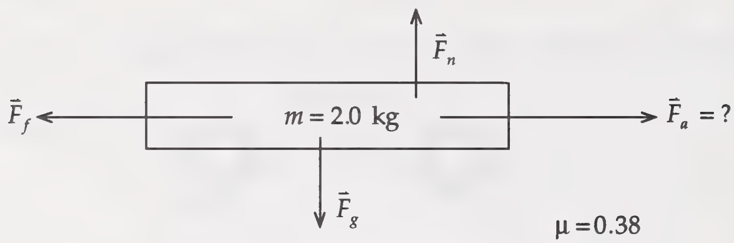
$$F_n = 8.8 \times 10^1 \text{ N}$$

Step 3: Find the coefficient of friction.

$$\begin{aligned}\mu &= \frac{F_f}{F_n}\\ &= \frac{2.0\ \text{N}}{8.8\times10^{1}\ \text{N}}\\ &= 0.023\end{aligned}$$

Textbook question 9:

Step 1: Find the normal force.



$$\begin{aligned}F_n &= F_g\\ &= mg\\ &= (2.0\ \text{kg})(9.80\ \text{m/s}^2)\\ &= 19.6\ \text{N}\end{aligned}$$

Step 2: Find the force of friction.

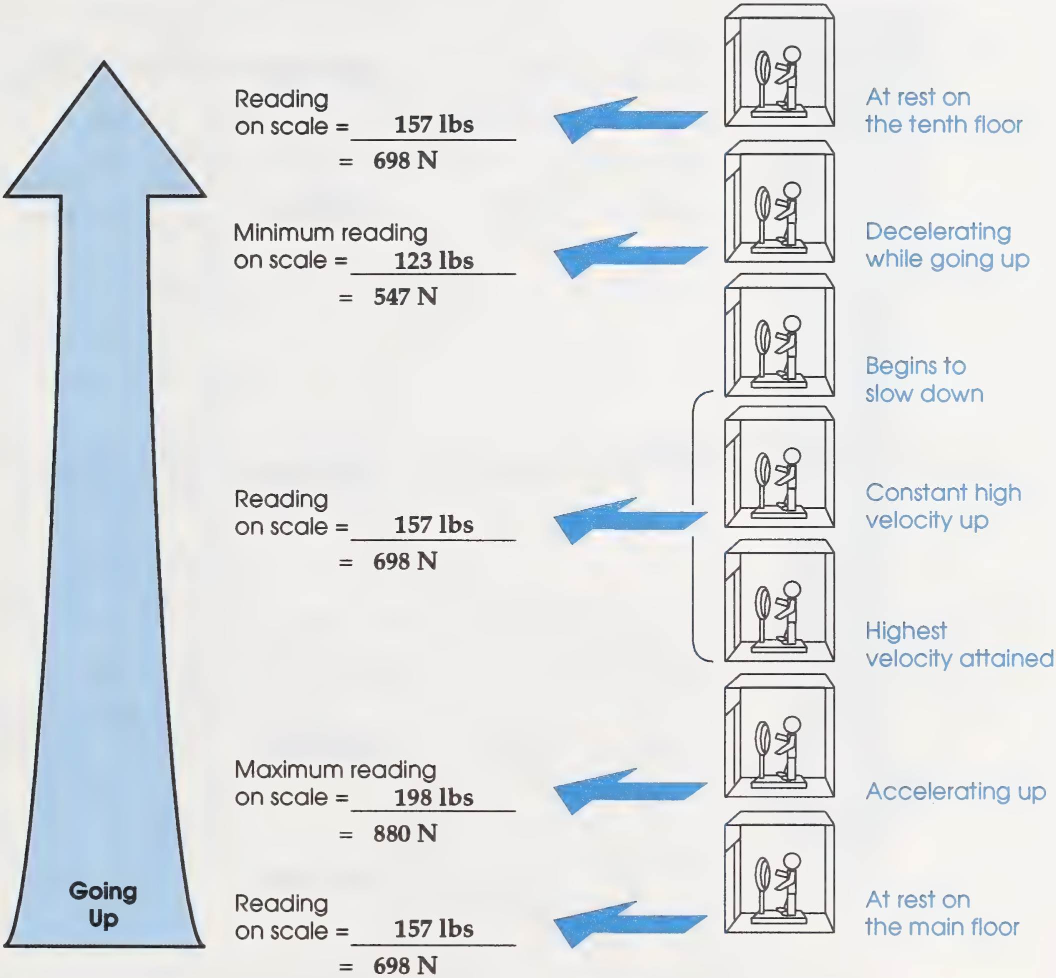
$$\begin{aligned}\mu &= \frac{F_f}{F_n}\\ F_f &= \mu F_n\\ &= (0.38)(19.6\ \text{N})\\ &= 7.448\ \text{N}\\ &= 7.5\ \text{N}\end{aligned}$$

Step 3: Since the brick moves at constant velocity, all the forces are balanced, according to Newton's first law.

$$F_a = 7.5\ \text{N}$$

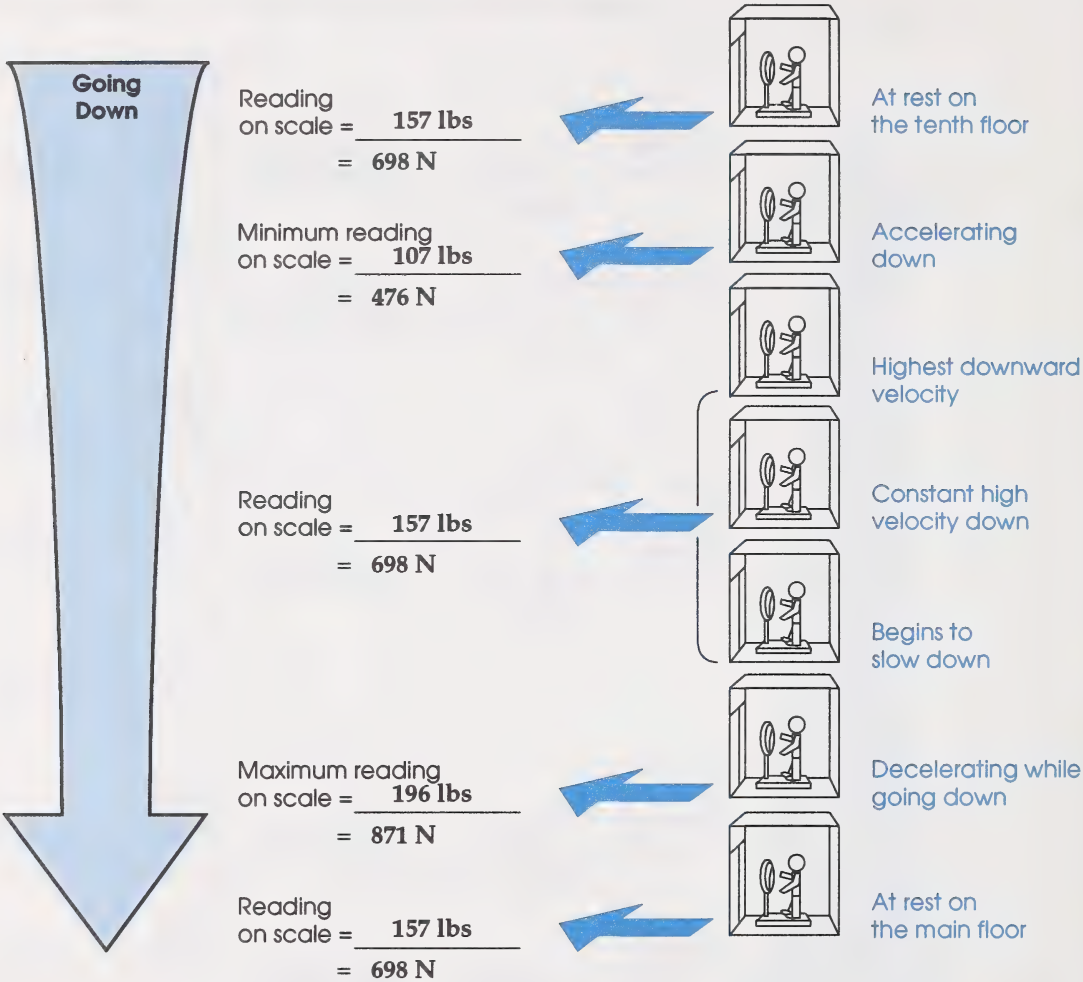
Section 2: Activity 2

1. Your answers may vary slightly from the samples provided due to difficulties in reading the scale.



2. This question is answered on the previous chart.

3. Your answers may vary slightly from the samples provided here due to difficulties in reading the scale.



4. Textbook question 1:

On upward elevator rides the scale reads larger values when the ride starts to move up and lower values when the scale begins to stop. On downward elevator rides the scale reads smaller values when the ride starts down and larger values when the ride stops.

5. Textbook question 1:

   The scale reads a normal value when the elevator is at rest and when it is moving with uniform motion between floors. According to Newton's first law, the forces would be balanced in these circumstances.

   Textbook question 2:

   The scale reads a heavier value when starting on the way up and stopping on the way down. In both cases the acceleration is upward and so F_{net} is upward.

   Textbook question 3:

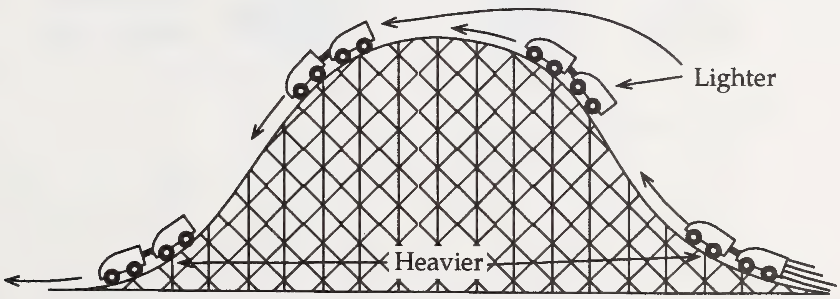
   The scale reads a lighter value when stopping on the way up and starting on the way down. In both cases the acceleration is downward and so is F_{net}.

6. Textbook question 1:

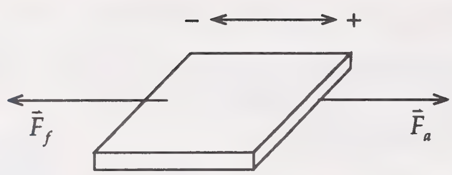
   An escalator moves with uniform motion, so the forces should be balanced, producing no sensation of being lighter or heavier. The only exception to this occurs when getting on or off the escalator.

   Textbook question 2:

   The situation for a roller coaster would be very similar to a ride on an elevator. You would feel heavier as you start moving up a hill and as you come to the bottom of a hill. You would feel lighter as you begin dropping down a hill and as you suddenly reach the top of a hill.



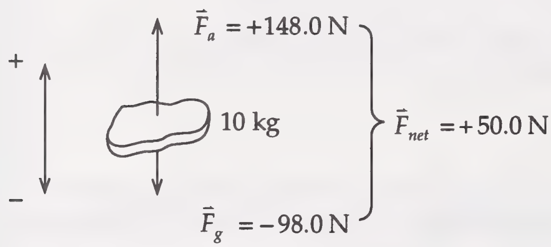
7. a.



Throughout the explanation, the applied force is in the positive direction and the force of friction is in the negative direction.

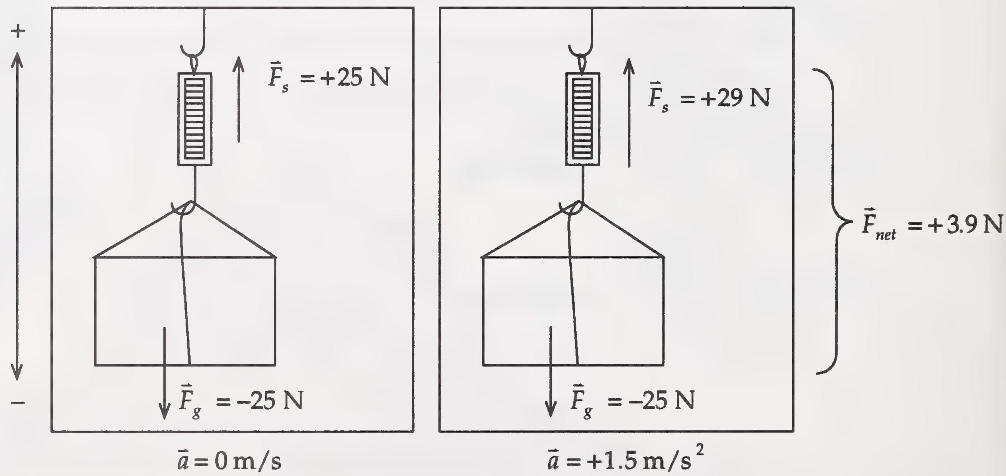
b. The force of friction is −20 N because it is directed to the left, the negative direction.

8. a.



b. See the labels on the previous diagram.

9.



10. a. Newton's second law states that $\vec{F} = m\vec{a}$. If the acceleration is zero, the net force must also be zero in order to satisfy the equation.

b. Newton's first law of motion states that for an object to be at rest, all the forces must be balanced. In other words, the net force must be zero.

11. a. The two equations given for net force were $\vec{F}_{net} = m\vec{a}$ and $\vec{F}_{net} = \vec{F}_{scale} + \vec{F}_g$.

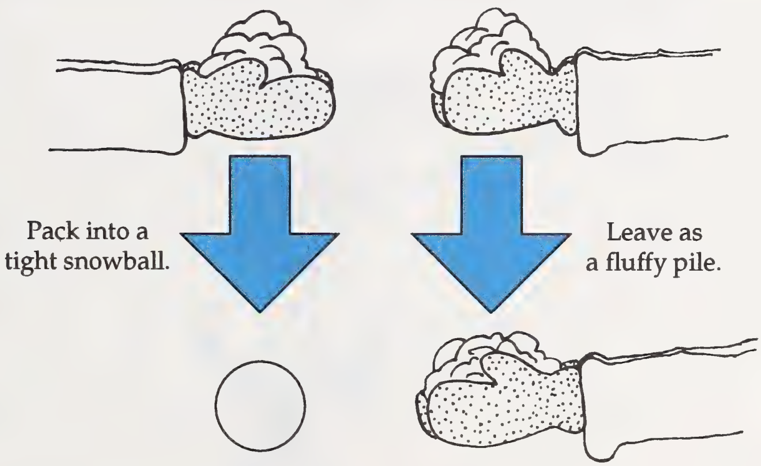
    b. The first equation, $\vec{F}_{net} = m\vec{a}$, is a statement of Newton's second law of motion. The net force on an object will cause an object to accelerate in the direction of the net force. The second equation describes how net force is determined from the other forces. The net force is what remains or what is unbalanced after all the forces acting on an object have been added together as vectors.

12. Answers to these questions can be found on page 663 of your textbook.

13. Since you are making an educated guess here, answers will vary. You may have mentioned that large snowflakes have a large surface area as compared to their mass and they tend to "flutter" as they fall.

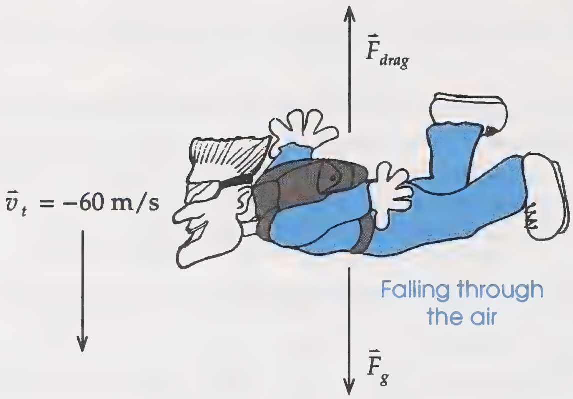
14. Terminal velocity is the maximum velocity of a falling object. At this velocity the drag force balances the force of gravity, producing uniform motion.

15. A similar demonstration for snow could be done by taking two equal amounts of snow and preparing them as follows:



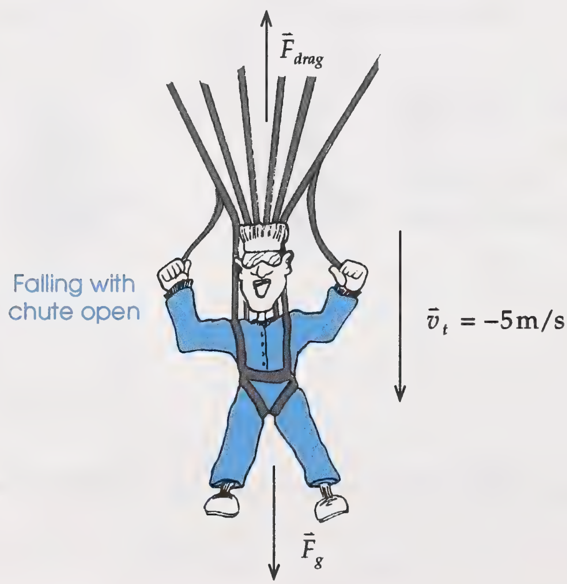
Drop each sample from the same height and note which sample strikes the ground first.

16.

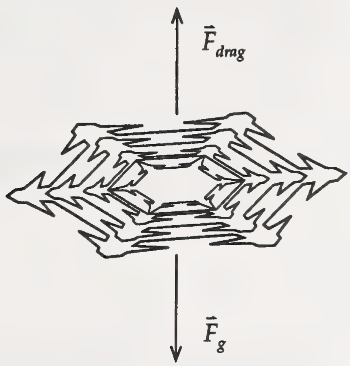


The free falling skydivers control their velocity by controlling their body shape. The spread-eagle position allows the skydiver to reach a velocity of -60 m/s before the force of air resistance or drag force equals the force of gravity.

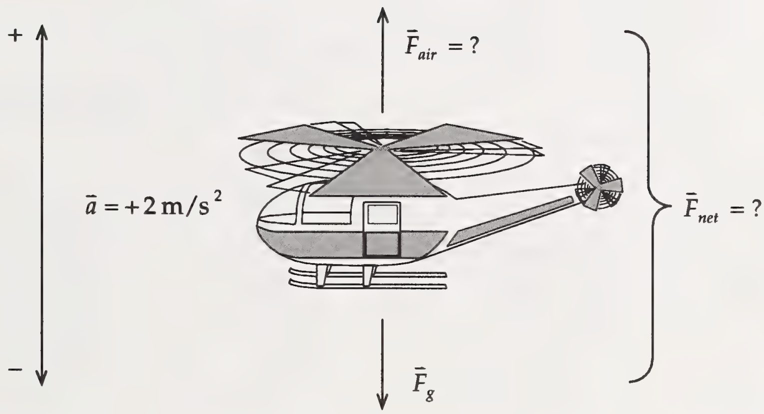
The lowest terminal velocity possible occurs when the parachute is open. In this case the very large surface area results in a drag force which equals the force of gravity at a velocity of -5 m/s.



17. Large snowflakes have a low terminal velocity due to their large surface area. This shape causes the force of air resistance to become as large as the force of gravity at low velocities.



18. Textbook question 18:



Step 1: Find the weight of the helicopter.

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (4500\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -44\,100\ \text{N}\\ &= -4.41\times10^4\ \text{N}\end{aligned}$$

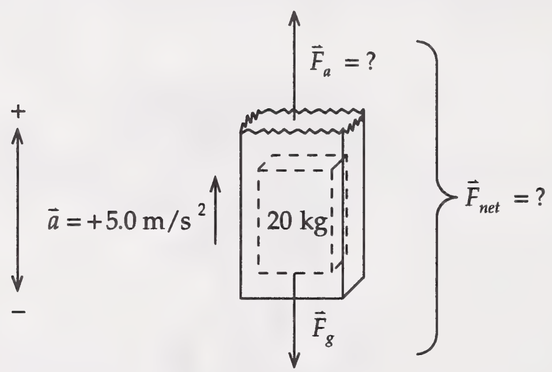
Step 2: Find the net force.

$$\begin{aligned}\vec{F}_{net} &= m\vec{a}\\ &= (4500\ \text{kg})(2\ \text{m/s}^2)\\ &= 9000\ \text{N}\\ &= 9\times10^3\ \text{N}\end{aligned}$$

Step 3: Find the force of the air on the propellers.

$$\begin{aligned}\vec{F}_{net} &= \vec{F}_{air} + \vec{F}_g\\ \vec{F}_{air} &= \vec{F}_{net} - \vec{F}_g\\ &= (9\times10^3\ \text{N}) - (-4.41\times10^4\ \text{N})\\ &= 5.3\times10^4\ \text{N}\end{aligned}$$

Textbook question 19:



Step 1: Find the weight of the grocery bag.

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (20\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -196\ \text{N}\\ &= -1.96\times10^2\ \text{N}\end{aligned}$$

Step 2: Find the net force.

$$\begin{aligned}\vec{F}_{net} &= m\vec{a}\\ &= (20\text{ kg})(5.0\text{ m/s}^2)\\ &= 1.0\times10^2\text{ N}\end{aligned}$$

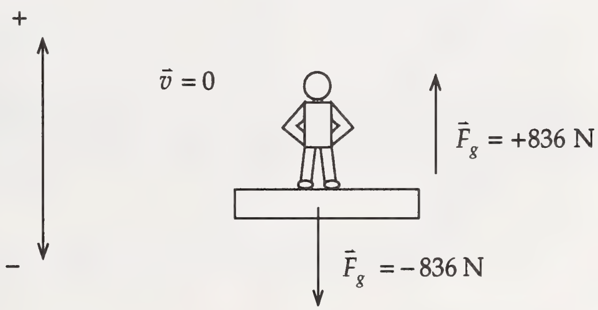
Step 3: Find the applied force.

$$\begin{aligned}\vec{F}_{net} &= \vec{F}_a + \vec{F}_g\\ \vec{F}_a &= \vec{F}_{net} - \vec{F}_g\\ &= (1.0\times10^2\text{ N})-(-1.96\times10^2\text{ N})\\ &= 2.96\times10^2\text{ N}\\ &= 3.0\times10^2\text{ N}\end{aligned}$$

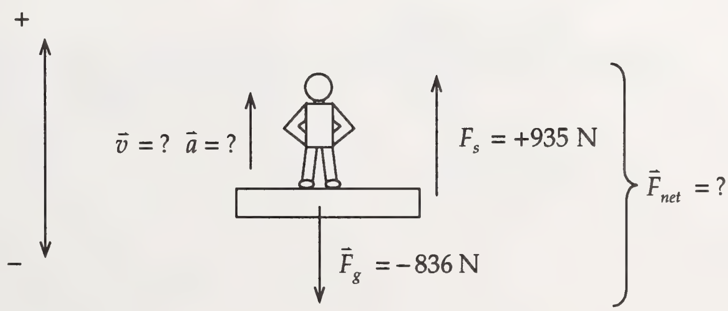
Since the bag can only withstand 250 N, it will rip.

Textbook question 20. a.:

While at rest, the weight and the force of the scale balance, according to Newton's first law.



While starting to move up, there is a $\vec{F}_{net}$ which creates an upward acceleration.



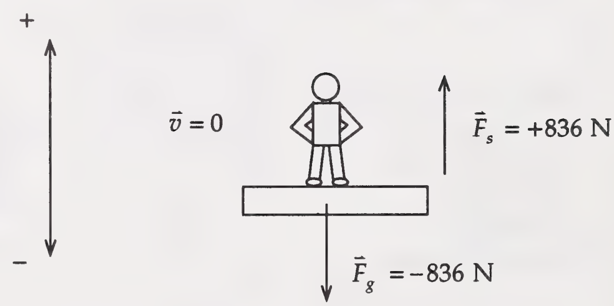
Step 1:
$$\vec{F}_{net} = \vec{F}_s + \vec{F}_g$$
$$= (935\text{ N}) + (-836\text{ N})$$
$$= 99\text{ N}$$

Step 2:
$$\vec{F}_g = m\vec{g}$$
$$m = \frac{\vec{F}_g}{\vec{g}}$$
$$= \frac{-836\text{ N}}{-9.80\text{ m/s}^2}$$
$$= 85.3\text{ kg}$$

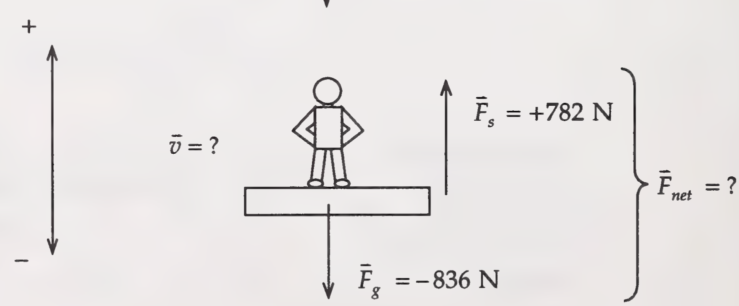
Step 3:
$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{99\text{ N}}{85.3\text{ kg}}$$
$$= 1.16\text{ m/s}^2$$
$$= 1.2\text{ m/s}^2$$

Textbook question 20. b.:

While at rest, the weight and the force of the scale balance, according to Newton's first law of motion.



While starting to slow down, there is a $\vec{F}_{net}$ which creates a downward acceleration.



Step 1: Find the net force.

$$\begin{aligned}\vec{F}_{net} &= \vec{F}_s + \vec{F}_g \\ &= (782\text{ N}) + (-836\text{ N}) \\ &= -54\text{ N}\end{aligned}$$

Step 2: Find the mass of the student. This was already calculated in question 20. a.

$$m = 85.3\text{ kg}$$

Step 3: Find the acceleration.

$$\begin{aligned}\vec{F}_{net} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m} \\ &= \frac{-54\text{ N}}{85.3\text{ kg}} \\ &= -0.633\text{ m/s}^2 \\ &= -0.63\text{ m/s}^2\end{aligned}$$

Textbook question 20. c.:

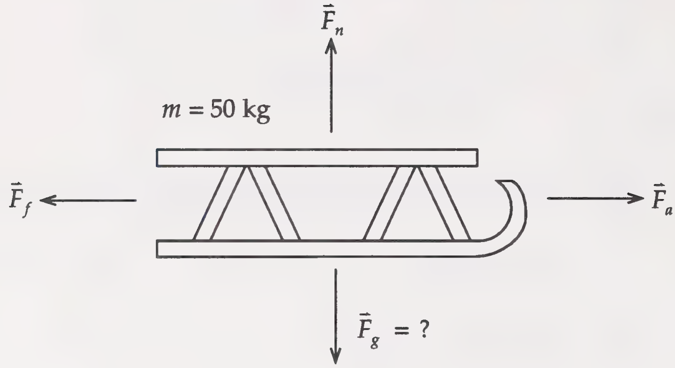
If you use the equation $\vec{a} = \Delta\vec{v} / \Delta t$ and rearrange to solve for t, the resulting equation is $\Delta t = \Delta\vec{v} / \vec{a}$. If the change in velocity is constant, a smaller acceleration will cause the change in time to be larger than the change caused by a larger acceleration.

Since the acceleration was smaller for stopping, stopping should take more time.

Textbook question 20. d.:

The scale will read a smaller value when the elevator starts to move down and a larger value when it stops at the lower floor.

Textbook question 22. a.:



$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= (50\ \text{kg})(-9.80\ \text{m/s}^2)\\ &= -490\ \text{N}\end{aligned}$$

Textbook question 22. b.:

F_n is the force that balances the weight of the sled. In order to get the sled moving, you must overcome the force of static friction. Therefore, calculate the force of friction by using F_n and the coefficient of static friction.

$$\mu = \frac{F_f}{F_n}$$

$$\begin{aligned}F_f &= \mu F_n\\ &= (0.30)(490\ \text{N})\\ &= 147\ \text{N}\\ &= 1.5\times 10^2\ \text{N}\end{aligned}$$

The sled will start to move when the applied force is at least equal to the force of friction. Therefore, $F_a = 1.5\times 10^2$ N.

Textbook question 22. c.:

Use the coefficient of sliding friction to calculate the force needed to keep the sled moving.

$$\mu = \frac{F_f}{F_n}$$

$$\begin{aligned} F_f &= \mu F_n \\ &= (0.10)(490 \text{ N}) \\ &= 49 \text{ N} \end{aligned}$$

The sled will move at a constant velocity when the applied force is equal to the force of friction. Therefore, $F_a = 49 \text{ N}$.

Textbook question 22. d.:

Step 1: Find $\vec{F}_{net}$.

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ &= (50 \text{ kg})(3.0 \text{ m/s}^2) \\ &= 1.5 \times 10^2 \text{ N} \end{aligned}$$

Step 2: Find $\vec{F}_a$.

$$\begin{aligned} \vec{F}_{net} &= \vec{F}_a + \vec{F}_f \\ \vec{F}_a &= \vec{F}_{net} - \vec{F}_f \\ &= (1.5 \times 10^2 \text{ N}) - (-49 \text{ N}) \\ &= 199 \text{ N} \\ &= 2.0 \times 10^2 \text{ N} \end{aligned}$$

Section 2: Activity 3

1. a. The puck maintains nearly constant velocity because there are almost no unbalanced forces acting on it. This is in accordance with Newton's first law.

   b. The player pushes against the ice and the ice pushes back with an equal force in the opposite direction. This is described in Newton's third law of motion.

   c. To change the velocity of the puck means that the puck will accelerate. The puck will accelerate in the direction of the unbalanced force which is supplied by the stick.

2. Momentum is the product of an object's mass and its velocity $(\vec{p} = m\vec{v})$.

3. An object with a very small amount of momentum would have a small mass and a low velocity. A ladybug crawling across this page would have a small amount of momentum.

4. An object with a large amount of momentum would have a large mass and would be travelling at a high velocity. A jet would have a large amount of momentum.

5. Both objects have the same amount of momentum, which measures quantity of motion. One has a large mass, the other has a large velocity, but since it is the product of mass and velocity that matters, the momentum is the same.

6. The answer to this question is found on page 669 of the textbook.

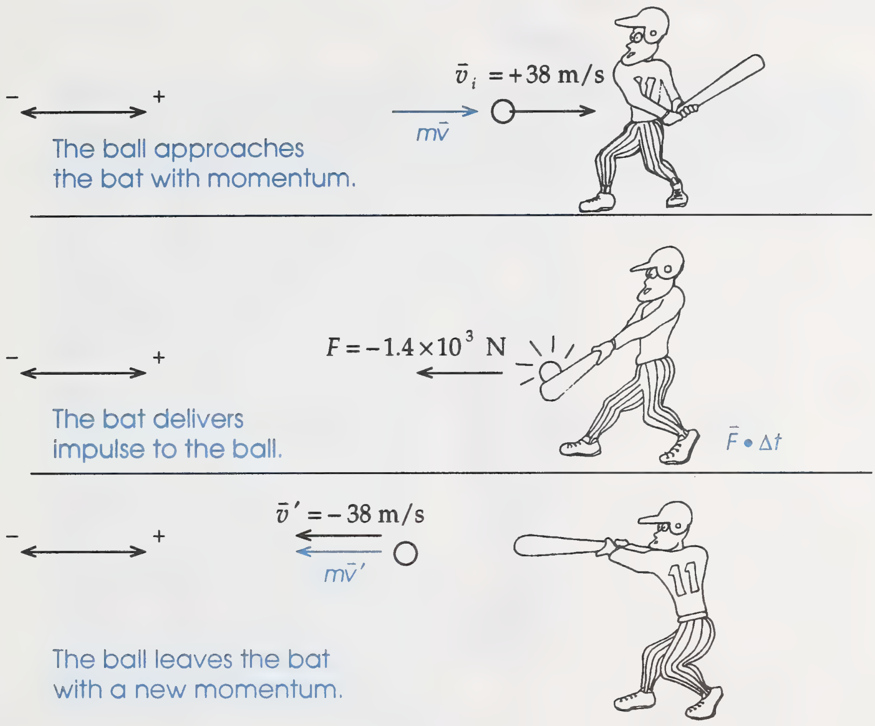
7. A single object will tend to maintain its momentum unless an unbalanced force acts on it.

8. Impulse is the product of the force acting on an object and the time interval over which that force acts $\left(\text{Impulse} = F(\Delta t)\right)$.

9.

Writing Newton's Second Law in Terms of Momentum	
Equations	**Brief Description**
$\vec{F} = m\vec{a}$	Newton's second law
$\vec{F} = m\left(\frac{\Delta \vec{v}}{\Delta t}\right)$	Acceleration is equal to change in velocity divided by change in time. $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$
$\vec{F}(\Delta t) = (m)\left(\frac{\Delta \vec{v}}{\Delta t}\right)(\Delta t)$	Multiplying both sides of the equations by Δt does not change the equality of the equation.
$\vec{F}(\Delta t) = (m)\left(\frac{\Delta \vec{v}}{\cancel{\Delta t}}\right)(\cancel{\Delta t})$	Change in time cancels on the right hand side.
$\vec{F}(\Delta t) = m(\Delta \vec{v})$	Since $\vec{p} = m\vec{v}$, $\Delta \vec{p} = m(\Delta \vec{v})$. Therefore, the impulse given to an object equals its change in momentum.
$\vec{F}(\Delta t) = \Delta \vec{p}$	

10. Answers for a., b., and c. are shown in the diagrams.



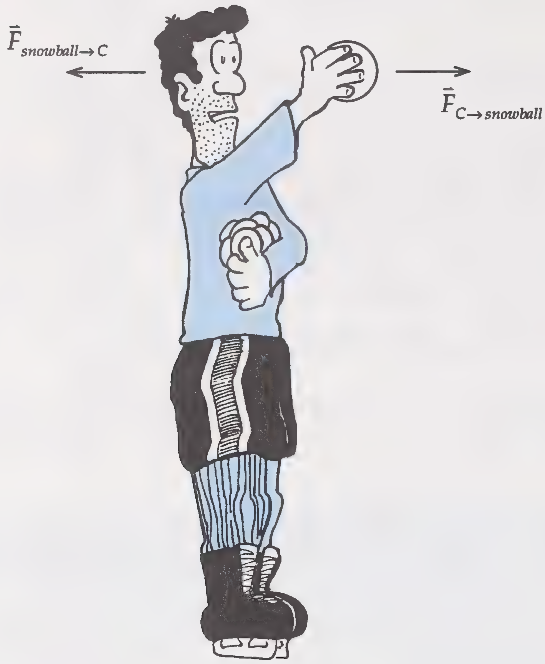
11. When a driver experiences a head-on crash, the momentum of the driver's body must change. This change in momentum of the body is equal to the impulse that the body experiences as it collides with the inside of the car.

$$\underbrace{\vec{F}(\Delta t)}_{\text{impulse}} = \underbrace{\Delta \vec{p}}_{\text{change in momentum}}$$

Life-threatening injuries are due to large forces acting during a very brief period of time. To save the driver's life, it is better to have a smaller force acting over a longer time. Seatbelts and airbags help to slow down the driver's body over a longer period of time, reducing the force on the body. Another point about seatbelts and airbags is that they spread the force out over a much larger area on the driver's body. This also helps to reduce the seriousness of injury to any one part of the driver, especially the head.

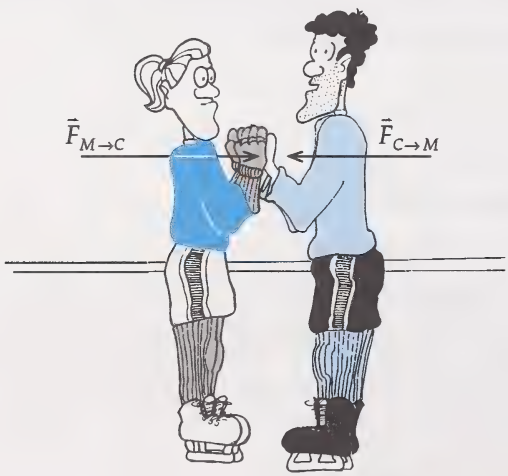
12. These questions are answered on page 669 of the textbook.

13. a.



b. Since Cameron can only exert a small force on the snowball, the reaction force back on him is also small.

14.



15. When Cameron pushed on Marie (providing an action force), he would automatically get an equal but opposite reaction force back. Marie would not have to do anything. This happens as a result of Newton's third law.

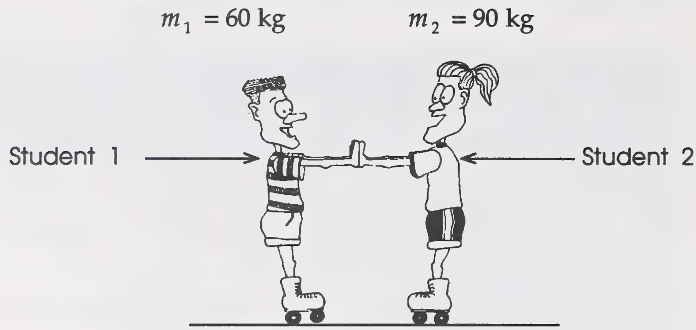
16.

Writing Newton's Third Law in Terms of Momentum	
Analysis	**Explanation**
$\vec{F}_{C\rightarrow M} = -\vec{F}_{M\rightarrow C}$	Newton's third law: Each force is equal but opposite.
$m_C(\vec{a}_C) = -m_M(\vec{a}_M)$	Substituting Newtons second law.
$m_C\left(\frac{\Delta\vec{v}_C}{\Delta t}\right) = -m_M\left(\frac{\Delta\vec{v}_M}{\Delta t}\right)$	Replacing $\vec{a}$ with $\frac{\Delta\vec{v}}{\Delta t}$.
$m_C(\Delta\vec{v}_C) = -m_M(\Delta\vec{v}_M)$	Multiply through by time. They are in contact for the same amount of time.
$\Delta\vec{p}_C = -\Delta\vec{p}_M$	If $\vec{p} = m\vec{v}$, $\Delta\vec{p} = m\Delta\vec{v}$.
$\vec{F}_{M\rightarrow C}(\Delta t) = -\vec{F}_{C\rightarrow M}(\Delta t)$	Definition of impulse since $\vec{F}\Delta t = \Delta\vec{p}$.

17. The impulse that Cameron delivers to Marie is equal but opposite to the impulse that Marie delivers to Cameron.

18. The change in Marie's momentum is equal but opposite in direction to the change in Cameron's momentum.

19. Textbook question 23:



$$\Delta \vec{p}_1 = -\Delta \vec{p}_2$$
$$m_1(\vec{v}_1' - \vec{v}_1) = -m_2(\vec{v}_2' - \vec{v}_2)$$

Since the initial velocities are zero, the equation can be written as follows:

$$m_1(\vec{v}_1') = -m_2(\vec{v}_2')$$
$$\frac{(\vec{v}_1')}{(\vec{v}_2')} = \frac{-m_2}{m_1}$$
$$= \frac{90 \text{ kg}}{60 \text{ kg}}$$
$$= 1.5$$

The smaller student will have a velocity one and a half times larger than that of the larger student.

Section 2: Follow-up Activities

Extra Help

1.

Comparison Chart for New Terms

	Coefficient of Friction	Normal Force	Net Force	Momentum	Impulse
Symbol	μ	$\vec{F}_n$	$\vec{F}_{net}$	$\vec{p}$	$\vec{F}(\Delta t)$
Brief Description	This is a constant that depends on the two surfaces in contact.	This is the force that acts perpen-dicular to two surfaces to push them together.	This is the force that remains unbalanced when all the forces have been added as vectors. This is in Newton's second law.	This is the product of an object's mass and its velocity.	This is the product of a force and the time interval over which the force acts.
Equations that Include this Term	$\mu = \frac{F_f}{F_n}$	For horizontal surfaces: $\vec{F}_n = -\vec{F}_g$	$\vec{F}_{net} =$ the sum of all forces $\vec{F}_{net} = m\vec{a}$	$\vec{p} = m\vec{v}$	$\vec{F}(\Delta t) = \Delta\vec{p}$

2.

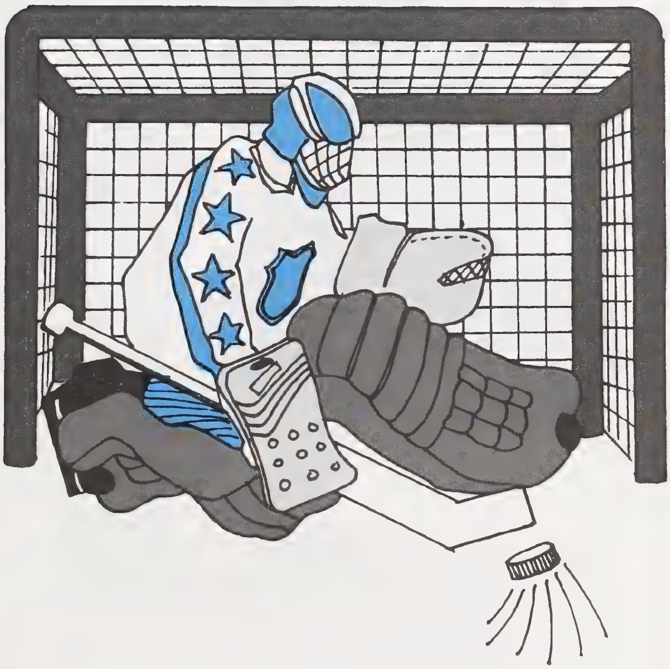
	Newton's Laws Comparison Chart	
	Described in Terms of Forces and Acceleration	**Described in Terms of Momentum and Impulse**
Newton's First Law of Motion	An object will maintain its velocity unless acted on by an unbalanced force.	An object will maintain its momentum unless acted on by an unbalanced force.
Newton's Second Law of Motion	An unbalanced force will cause an object to accelerate in the direction of the force, according to $\vec{F}_{net} = m\vec{a}$.	An impulse will cause a change in the momentum of an object, according to $\vec{F}(\Delta t) = \Delta\vec{p}$.
Newton's Third Law of Motion	For every action force there is an equal but opposite reaction force. $\vec{F}_{1\rightarrow 2} = -\vec{F}_{2\rightarrow 1}$	When two objects interact, the change in momentum of one object is equal but opposite to the change in momentum in the other object.

Enrichment

1. Answers will vary, depending on the sports and the individual cards chosen. Samples are given for hockey cards.

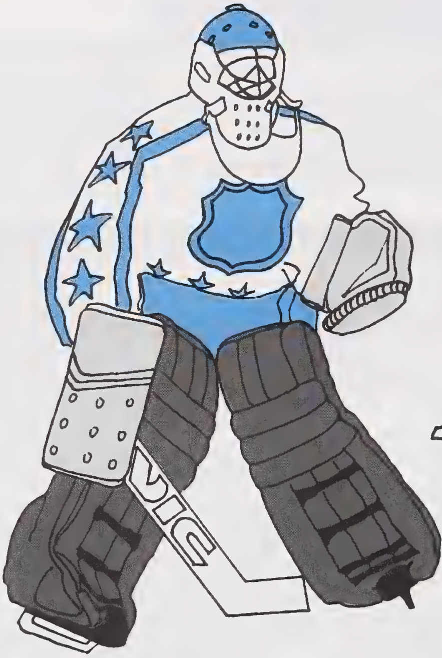
   You must be very specific about what object you are describing and you should also clearly link that object to the law.

Newton's First Law



The puck shown in this picture will maintain its velocity and pass through the goalie's legs unless the goalie can exert a force on it.

Newton's Second Law



For this player to accelerate to a higher velocity, a force is required in the direction of the acceleration.

$$\vec{F}_{net} = m\vec{a}$$

For a goalie to stop a puck, there must be a change in the momentum of the puck. This requires the goalie to deliver an impulse to the puck.

$$\vec{F}(\Delta t) = m(\Delta \vec{v})$$

The padding increases the time over which the force acts. This means the force can be smaller and safer for the goalie.

Newton's Third Law

This player is using skates to exert a large force on the ice. This is the action force. The ice provides a reaction force that is equal in size but opposite in direction on the player.

$$\vec{F}_{player \to ice} = -\vec{F}_{ice \to player}$$

2. Observations and data will vary, depending on the individual carts used, but the tendency in the data and answers should be the same. Sample results are provided.

Observations and Data

Textbook question 1:

The lighter cart moved further.

Textbook question 2:

The lighter cart travelled faster because it covered a larger distance in the same time.

Analysis

Textbook question 1:

The lighter cart had about 50 percent more velocity than the heavier cart.

Textbook question 2:

The heavier cart had about 50 percent more mass, but it had a lower velocity. The lighter cart had about 50 percent more velocity, but it had less mass. The overall effect would be that each cart would have about the same amount of momentum. Since the carts go in opposite directions, one momentum would be positive and the other would be negative.

Textbook question 3:

The forces can only act for the length of time that the carts are in contact. Since the contact time is the same for both carts, the time for cart 2 would also be 0.05 s.

Textbook question 4:

Since the change in momentum for each of the carts is equal in size but opposite in direction, $\Delta\vec{p}_1 = -\Delta\vec{p}_2$.

The change in momentum of a cart equals the impulse applied to the cart, as given by Newton's second law:

$$\vec{F}_1\Delta t = \Delta\vec{p}_1 \qquad \vec{F}_2\Delta t = \Delta\vec{p}_2$$

If $\Delta\vec{p}_1 = -\Delta\vec{p}_2$, $\vec{F}_1\Delta t_1 = -\vec{F}_2\Delta t_2$ by substitution.

Since the time intervals are the same, $\Delta t_1 = \Delta t_2$ and $\vec{F}_1 = -\vec{F}_2$.

Applications

Textbook question 1:

A more massive gun would have a smaller velocity after being fired. This would be advantageous to the target shooter because the velocity of the gun after being shot (the recoil velocity) delivers an uncomfortable "kick" to the body of the shooter.

3. Check the answers given at the back of the Critical Thinking booklet in the teacher resource package.

Section 3: Activity 1

The answers for questions 1 to 13 are based on measurements made on the map in your module booklet. Your answers may vary slightly from the samples provided.

1. They need to travel 550 m.

2. They found the message at the south end of the path in the Dark Forest.

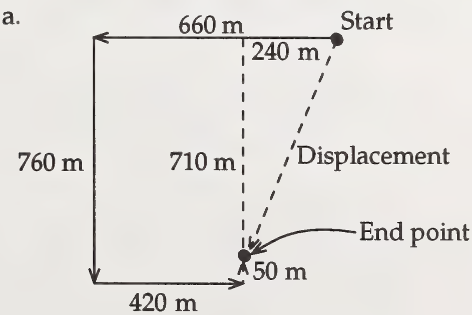
3.
$$\begin{aligned} A^2 + B^2 &= C^2 \\ (330\text{ m})^2 + (220\text{ m})^2 &= C^2 \\ C &= 397\text{ m} \\ &= 4.0 \times 10^2\text{ m} \end{aligned}$$

The displacement is 4.0×10^2 m northwest from Crash Corner. This could also be determined by measuring on the map.

4. The total distance to be travelled is 1890 m.

5. They will find this message at the salt lick.

6. a.

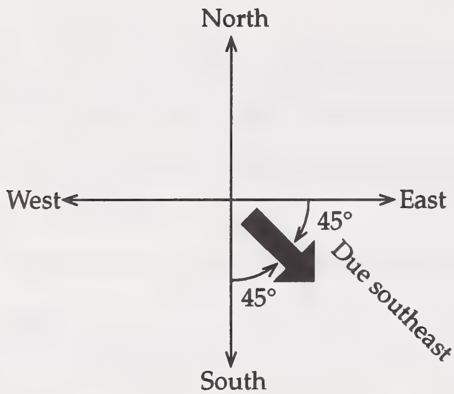


$$\begin{aligned} A^2 + B^2 &= C^2 \\ (240\text{ m})^2 + (710\text{ m})^2 &= C^2 \\ C &= 749\text{ m} \\ &= 7.5 \times 10^2\text{ m} \end{aligned}$$

The displacement from Base Camp is 7.5×10^2 m in a southwesterly direction. Another way to answer this would be to measure on the map.

7. The shortest path back is 7.5×10^2 m in a northeasterly direction.

8. a.



b. This direction could be abbreviated as S45°E or as E45°S.

9. The total distance travelled was 1620 m. The message was found at the dock on Deer Lake.

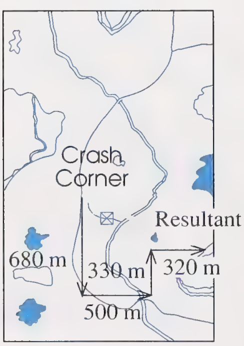
10. The displacement is about 1080 m, N37°E. In other words, the dock is 1080 m in a direction starting from north and going 37° east.

11. The Narrow Point Suspension Bridge should be used.

12. Answers may vary.

- From Crash Corner travel south 680 m.
- Travel east 500 m.
- Travel north 330 m.
- Travel east 320 m.

13.



14. a. Measuring produces a resultant displacement of 8.9×10^2 m.

$$A^2 + B^2 = C^2$$
$$(820\text{ m})^2 + (350\text{ m})^2 = C^2$$
$$C = 892\text{ m}$$
$$= 8.9 \times 10^2\text{ m}$$

b. $\tan\,\theta = \dfrac{\text{opposite}}{\text{adjacent}}$

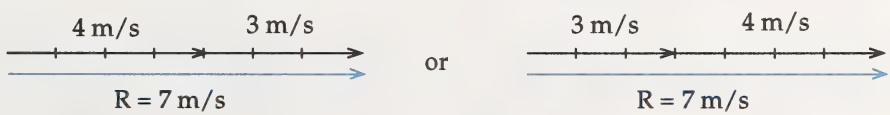
$\tan\,\theta = \dfrac{350\text{ m}}{820\text{ m}}$

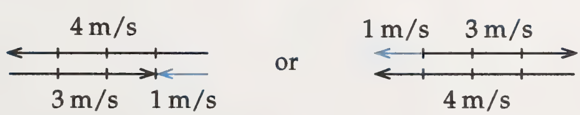
$\theta = 23.1°$

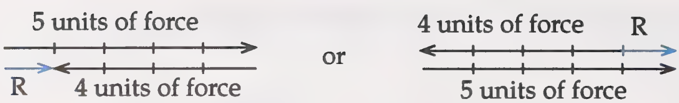
The angle is 23° south of east.

Section 3: Activity 2

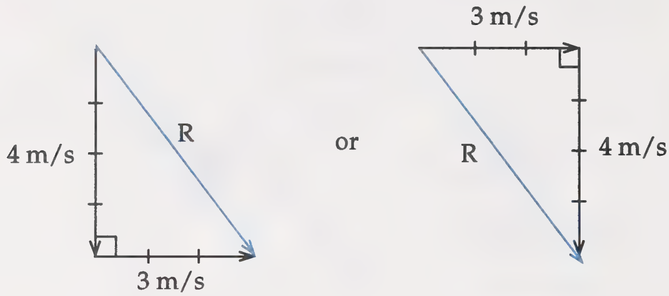
1. The magnitude of a vector is represented by the length of the line.
2. The direction of a vector is represented by the direction of the arrow.
3. The general rule that is followed when adding vectors is to place the tail of one vector at the head of the other vector.
4. The resultant vector is the single vector that could represent the sum of several vectors.
5. The resultant of vectors is a straight line drawn from the tail of the first vector to the head of the last vector.
6. It doesn't matter what order you add the vectors in. You will get the same resultant.





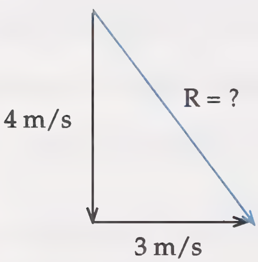
7. 

Either way, you get the same resultant – one unit of force to the right.

8. 

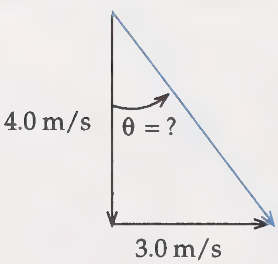
If the drawing is carefully done with a scale (for example 1 cm = 1 m/s), the resultant can be measured to be 5 m/s.

9. You can use the Pythagorean theorem to find the resultant when the vectors are at right angles to each other.

10. a. 

$$
\begin{aligned}
C^2 &= A^2 + B^2 \\
&= (3.0\ \text{m/s})^2 + (4.0\ \text{m/s})^2 \\
&= 9.0\ \text{m}^2/\text{s}^2 + 16.0\ \text{m}^2/\text{s}^2 \\
&= 25.0\ \text{m}^2/\text{s}^2 \\
C &= 5.0\ \text{m/s}
\end{aligned}
$$

The magnitude of the resultant velocity is 5.0 m/s.

b. 

$$
\begin{aligned}
\tan\theta &= \frac{\text{opposite}}{\text{adjacent}} \\
&= \frac{3.0\ \text{m/s}}{4.0\ \text{m/s}} \\
&= 0.75 \\
\theta &= 37^\circ
\end{aligned}
$$

The direction of the resultant velocity is S37°E or E53°S.

11. Textbook question 1:

$$\frac{20\ \text{m/s}}{30\ \text{m/s}} = \frac{x}{15\ \text{mm}}$$
$$x = 10\ \text{mm}$$

Since the scale is 1 mm for every 2 m/s, it would take 10 mm to represent 20 m/s.

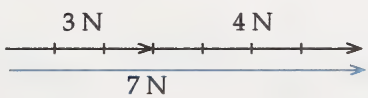
Textbook question 2:

$$\frac{1\ \text{cm}}{5\ \text{N}} = \frac{3\ \text{cm}}{x}$$
$$x = 15\ \text{N}$$

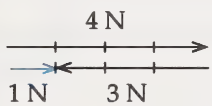
Since the scale is 1 cm for every 5 N, 3 cm would represent 15 N.

Textbook question 3:

The largest possible resultant force is 7 N.



The smallest possible resultant force is 1 N.



Textbook question 4. a.:

Pulling the toy in opposite directions would provide the smallest acceleration since the resultant force would only have a magnitude of 5 N.

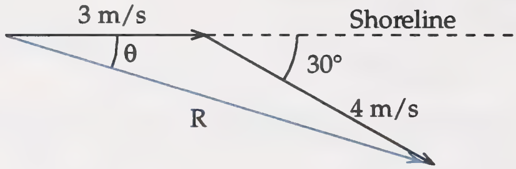
Textbook question 4. b.:

Two unequal forces can never add up to zero, so there could never be zero acceleration.

Textbook question 5:

As the angle between parallel vectors increases, the resultant vector decreases.

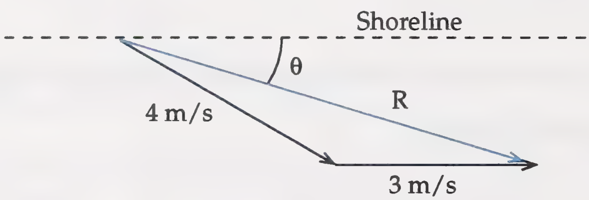
12. Check this solution closely. If you are going to draw vectors, you need to measure lengths and angles very carefully.



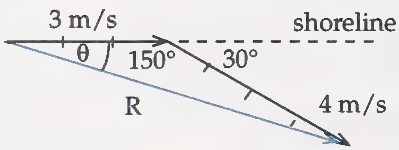
$R = 6.8$ m/s

The direction of the resultant is about 17° away from the shoreline.

You could also draw the vectors like this.



13.



To find the magnitude of the resultant use the law of cosines.

$$c^2 = a^2 + b^2 - 2ab\cos C$$

$$c^2 = (3\text{ m/s})^2 + (4\text{ m/s})^2 - 2(3\text{ m/s})(4\text{ m/s})(\cos 150°)$$

$$c = 6.8\text{ m/s}$$

To find the direction of the resultant use the law of sines.

$$\frac{a}{\sin A} = \frac{b}{\sin B}$$

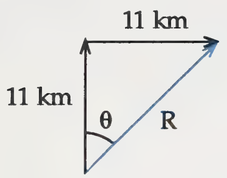
$$\frac{(6.8\text{ m/s})}{\sin 150°} = \frac{(4\text{ m/s})}{\sin \theta}$$

$$\theta = 17.2°$$

14. Textbook question 1. a.:

The total distance walked is 22 km. Distance is not a vector.

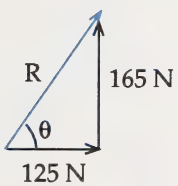
Textbook question 1. b.:



$$A^2 + B^2 = C^2$$
$$(11\text{ km})^2 + (11\text{ km})^2 = C^2$$
$$C = 16\text{ km}$$

The displacement is 16 km, N45°E.

Textbook question 2:



$$A^2 + B^2 = C^2$$
$$(165\text{ N})^2 + (125\text{ N})^2 = C^2$$
$$C = 207\text{ N}$$

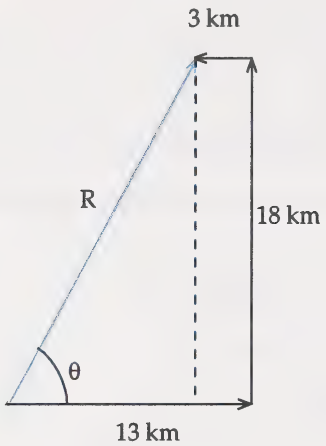
$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{165\text{ N}}{125\text{ N}}$$
$$\theta = 53°$$

The resultant force is 207 N, E53°N.

Textbook question 3. a.:

The total distance walked is 34 km.

Textbook question 3. b.:



$$A^2 + B^2 = C^2$$

$$(10 \text{ km})^2 + (18 \text{ km})^2 = C^2$$

$$C = 21 \text{ km}$$

$$\tan \theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$= \frac{18 \text{ km}}{13 \text{ km}}$$

$$\theta = 61°$$

The resulting displacement is 21 km, E61°N.

15. $v = \dfrac{d}{t}$

$$t = \frac{d}{v}$$

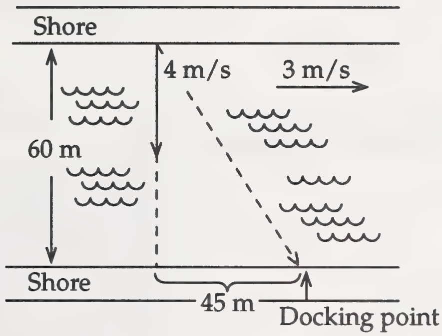
$$t = \frac{60 \text{ m}}{4 \text{ m/s}}$$

$$t = 15 \text{ s}$$

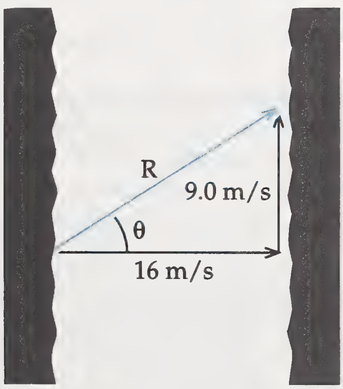
Because David makes progress across the river at 4 m/s, it will take him 15 s to cross the river.

$$d = vt$$
$$d = (3\ \text{m/s})(15\ \text{s})$$
$$d = 45\ \text{m}$$

Because he is on the river for 15 s, it will sweep him downstream 45 m.



16. Textbook question 4. a.:



$$A^2 + B^2 = C^2$$
$$(9.0\ \text{m/s})^2 + (16\ \text{m/s})^2 = C^2$$
$$C = 18\ \text{m/s}$$

$$\tan\theta = \frac{9.0\ \text{m/s}}{16\ \text{m/s}}$$
$$\theta = 29°$$

The resultant velocity is 18 m/s, E29°N.

Textbook question 4. b.:

$$v = \frac{d}{t}$$
$$t = \frac{d}{v}$$
$$t = \frac{136 \text{ m}}{16 \text{ m/s}}$$
$$t = 8.5 \text{ s}$$

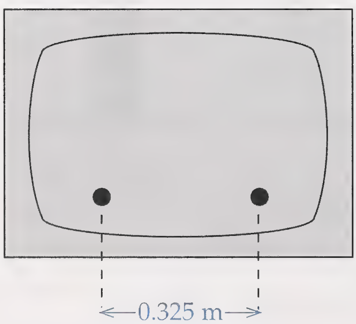
The boat makes progress across the river at the rate of 16 m/s. Therefore, it will take 8.5 s to reach the other side.

Textbook question 4. c.:

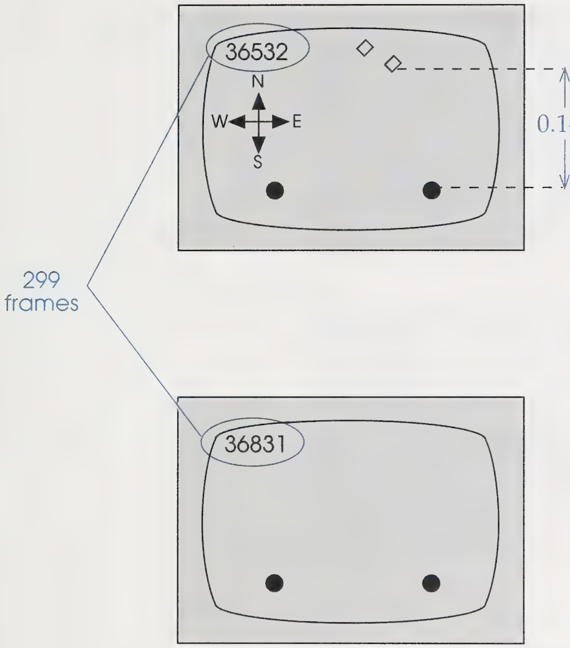
$$v = \frac{d}{t}$$
$$d = vt$$
$$d = (9.0 \text{ m/s})(8.5 \text{ s})$$
$$d = 77 \text{ m}$$

The boat is on the river for 8.5 s, so it will be swept 77 m downstream.

17. The answers shown illustrate sample data collected from a 20-inch television screen. Your data may vary from what is presented here, but your final value for velocity should be nearly the same.



$$\text{magnification} = \frac{10 \text{ m (on river)}}{0.325 \text{ m (on TV)}} = 30.77$$



- Calculate the displacement.

0.144 m × 30.77 = 4.43 m south

- Calculate the time.

$$299 \cancel{\text{ frames}} \times \left[\frac{1 \text{ s}}{36 \cancel{\text{ frames}}}\right] = 8.31 \text{ s}$$

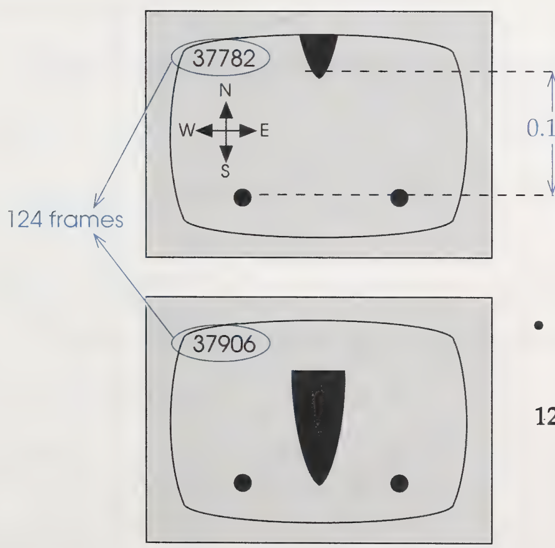
- Calculate the velocity.

$$\vec{v} = \frac{\vec{d}}{t}$$
$$= \frac{4.43 \text{ m south}}{8.31 \text{ s}}$$
$$= 0.53 \text{ m/s south}$$

Note that rounding off occurred at the end of the calculations.

Although the data you worked with may have differed from the sample values presented here, the final value for the velocity of the river should be close to 0.53 m/s south.

18.



0.197 m × 30.77 = 6.06 m south

- Calculate the time.

$$124 \text{ frames} \times \left[\frac{1 \text{ s}}{36 \text{ frames}}\right] = 3.44 \text{ s}$$

- Calculate the velocity of the boat and the river.

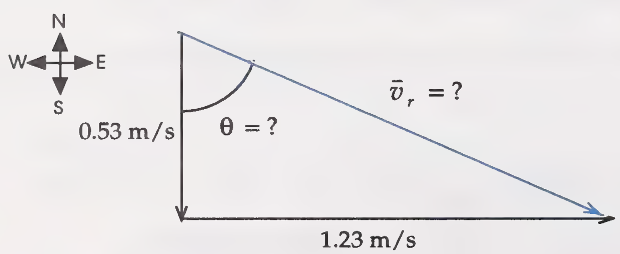
$$\vec{v}_{b+r} = \frac{\vec{d}}{t} = \frac{6.06 \text{ m south}}{3.44 \text{ s}} = 1.76 \text{ m/s south}$$

- Calculate the velocity of the boat.

$$\vec{v}_{b+r} = \vec{v}_b + \vec{v}_r$$
$$1.76 \text{ m/s south} = \vec{v}_b + 0.53 \text{ m/s south}$$
$$\vec{v}_b = 1.23 \text{ m/s south}$$

19. When the boat travels east, the velocity of the boat is 1.23 m/s east.

$$\vec{v}_{resultant} = \vec{v}_{river} + \vec{v}_{boat} = 0.43 \text{ m/s south} + 1.23 \text{ m/s east}$$

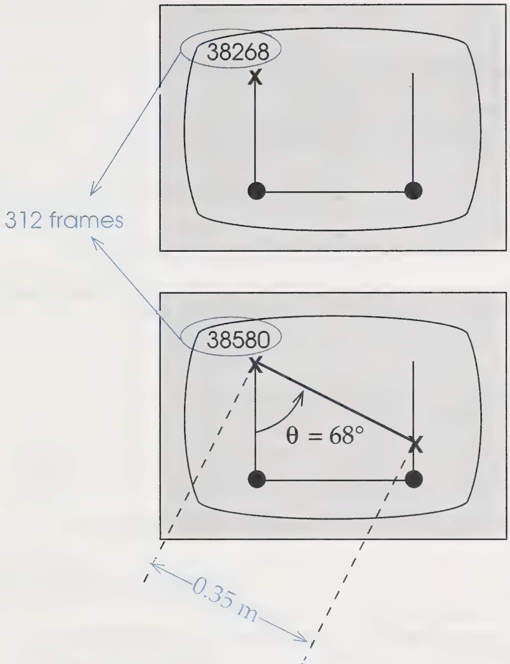


$$C^2 = A^2 + B^2$$
$$(v_r)^2 = (0.53 \text{ m/s})^2 + (1.23 \text{ m/s})^2$$
$$v_r = 1.3 \text{ m/s}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{1.23 \text{ m/s}}{0.53 \text{ m/s}}$$
$$\theta = 67°$$

The resultant velocity of the boat as it travels across the river should be 1.3 m/s, S67°E.

20.



- Calculate the displacement using the magnification factor of 30.77.

$0.35 \text{ m} \times 30.77 = 10.77 \text{ m}$

$\vec{d} = 10.77 \text{ m, S}68° \text{ E}$

- Calculate the time.

$$312 \text{ frames} \times \left[\frac{1 \text{ s}}{36 \text{ frames}}\right] = 8.67 \text{ s}$$

- Calculate the resultant velocity.

$$\vec{v}_r = \frac{\vec{d}}{t}$$
$$= \frac{10.77 \text{ m, S}68° \text{ E}}{8.67 \text{ s}}$$
$$= 1.24 \text{ m/s, S}68° \text{ E}$$

21. The magnitudes of the velocities compare well to each other. The directions differ only by 1° in the sample calculation. This could be due to errors in measuring displacements from the TV screen. Differences in the magnitudes of the velocities could also be attributed to measuring errors and possibly the inconsistent speed of the boat.

22. Textbook question 1:

The boat now has a forward and sideways component to its velocity.

Textbook question 2:

It did not go faster in the forward direction, but its speed increased relative to the floor.

Textbook question 3:

The boat still arrived at the other side of the river in the usual time.

Textbook question 4:

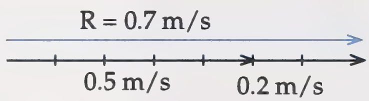
Because of bumps on the paper and floor, the boat would travel more uniformly if it was moving faster. However, the hydro engineer could overcome the friction of the floor even when he was pulling slowly. Answers will vary for this question.

23. Textbook question 1:

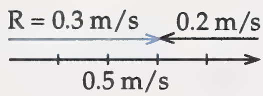
$$\text{ave. speed} = \frac{\text{total distance}}{\text{total time}}$$
$$= \frac{1.0 \text{ m}}{5 \text{ s}}$$
$$= 0.2 \text{ m/s}$$

The speed of the paper river was about 0.2 m/s. Answers may vary.

Textbook question 2:



Textbook question 3:



24. Textbook question 1:

Small aircraft can be blown off course by the wind. They will never fly sideways because they will always have a forward component to their velocity.

25. Vector quantities have both magnitude and direction.

26. Examples of vectors include velocity, displacement, acceleration, and force.

27. This video uses the expression "tip to tail."

28. To move straight across a fast-moving stream, you must aim your boat into the current and across the stream.

29. To decrease the tension in the rope you should increase angle θ by letting the weight hang lower.

30. Textbook question 1:

To add vectors graphically, the following steps are used:

- Decide on a scale that will allow you to draw each vector (e.g., 1 cm = 10 N).
- Draw the first vector.
- Draw the next vectors by starting each one at the head of the previous one.
- Draw the resultant from the tail of the first vector to the head of the last vector.
- Use the scale to determine the magnitude of the resultant.

Textbook question 2:

The vector can be moved, but its length and direction must stay the same.

Textbook question 3:

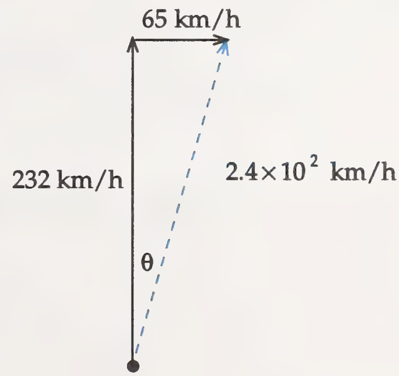
The resultant represents the combined effect of all the vectors. It is a single vector that can replace the sum of all the others.

Textbook question 6:

These vectors have the same magnitude but different directions.

Section 3: Activity 3

1.
$$A^2 + B^2 = C^2$$
$$(232 \text{ km/h})^2 + (65 \text{ km/h})^2 = C^2$$
$$C = 2.4 \times 10^2 \text{ km/h}$$

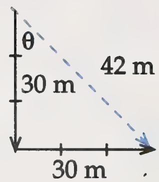


$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{65 \text{ km/h}}{232 \text{ km/h}}$$
$$\theta = 16°$$

The resultant velocity of the airplane is 2.4×10^2 km/h, N16°E.

2. Textbook question 9:

$$A^2 + B^2 = C^2$$
$$(30\text{ km})^2 + (30\text{ km})^2 = C^2$$
$$C = 42\text{ km}$$



$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{30}{30}$$
$$\theta = 45°$$

The resultant is 42 m, S45°E. The direction could simply be called due southeast.

Textbook question 10:

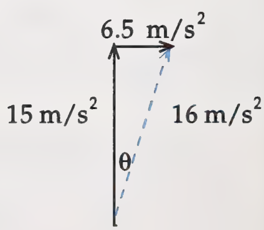
$$A^2 + B^2 = C^2$$
$$(100\text{ km})^2 + (500\text{ km})^2 = C^2$$
$$C = 510\text{ km}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{500}{100}$$
$$\theta = 78.7°$$

The ship must travel 510 km at an angle of W78.7°S or S11.3°W.

3. Textbook question 18:

$$A^2 + B^2 = C^2$$
$$(6.5\text{ m/s}^2)^2 + (15\text{ m/s}^2)^2 = C^2$$
$$C = 16\text{ m/s}^2$$

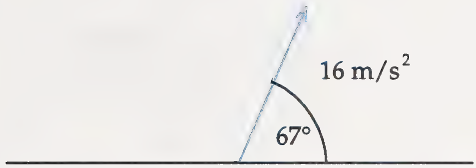


$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$= \frac{6.5\ \text{m/s}^2}{15\ \text{m/s}^2}$$

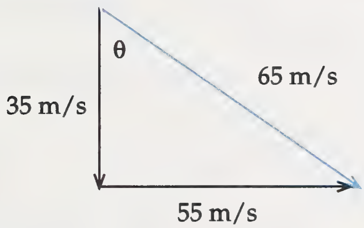
$$\theta = 23°$$

$$90° - 23° = 67°$$



The resultant acceleration is $16\ \text{m/s}^2$ at an angle of 67° to the horizontal.

Textbook question 19. a.:



$$A^2 + B^2 = C^2$$

$$(35\ \text{m/s})^2 + (55\ \text{m/s})^2 = C^2$$

$$C = 65\ \text{m/s}$$

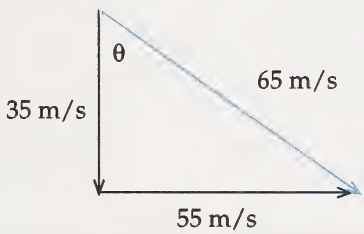
The descent vehicle has a resultant speed of 65 m/s. Speed is the magnitude of the velocity.

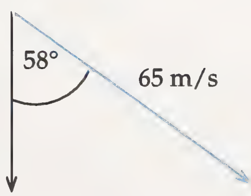
Textbook question 19. b.:

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$= \frac{55\ \text{m/s}}{35\ \text{m/s}}$$

$$\theta = 58°$$

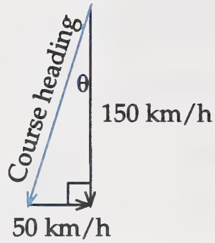




The descent vehicle moves at 58° to the vertical.

Textbook question 20:

$$\text{ave. speed} = \frac{\text{total distance}}{\text{total time}}$$
$$= \frac{450\ \text{km}}{3\ \text{h}}$$
$$= 150\ \text{km/h}$$

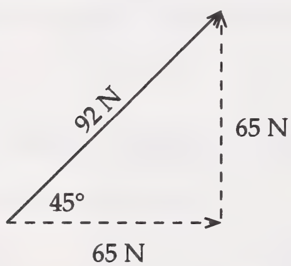


$$A^2 + B^2 = C^2$$
$$(50\ \text{km/h})^2 + (150\ \text{km/h})^2 = C^2$$
$$C = 158\ \text{km/h}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{50\ \text{km/h}}{150\ \text{km/h}}$$
$$\theta = 18°$$

Kyle should fly 158 km/h in the direction S18°W.

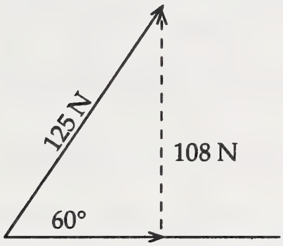
4. Textbook question 21:



$$F_h = 92\ \text{N}(\cos 45°)$$
$$= 65\ \text{N}$$

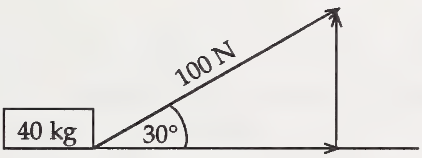
$$F_v = 92\ \text{N}(\sin 45°)$$
$$= 65\ \text{N}$$

Textbook question 22:



$$F_v = 125\text{ N}(\sin 60°)$$
$$= 108\text{ N}$$

Textbook question 23. a.:



$$F_h = 100\text{ N}(\cos 30°)$$
$$= 86.6\text{ N}$$

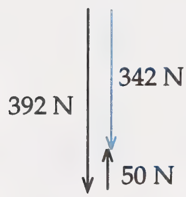
$$F = ma$$
$$a = \frac{F}{m}$$
$$a = \frac{86.6\text{ N}}{40\text{ kg}}$$
$$a = 2.2\text{ m/s}^2$$

The acceleration of the crate is 2.2 m/s^2.

Textbook question 23. b.:

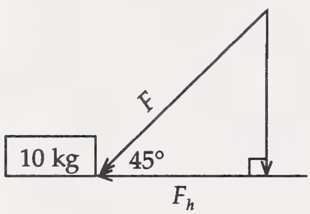
$$\begin{aligned} F_g &= mg \\ &= (40\ \text{kg})(9.80\ \text{m/s}^2) \\ &= 392\ \text{N} \end{aligned}$$

$$\begin{aligned} F_v &= 100\ \text{N}(\sin 30°) \\ &= 50\ \text{N} \end{aligned}$$



The ice exerts a force of 3.4×10^2 N upward on the crate.

Textbook question 24:



$$F = ma$$

$$\begin{aligned} F &= m\left(\frac{v_f - v_i}{t}\right) \\ &= 10\ \text{kg}\left(\frac{1.39\ \text{m/s} - 0}{1.5\ \text{s}}\right) \\ &= 9.27\ \text{N} \end{aligned}$$

$$F_h = F(\cos 45°)$$

$$\frac{F_h}{\cos 45°} = F$$

$$\begin{aligned} F &= \frac{9.27\ \text{N}}{\cos 45°} \\ &= 13\ \text{N} \end{aligned}$$

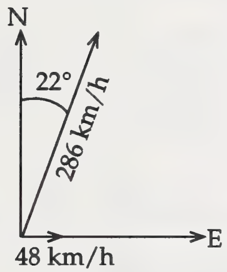
5. a. Another way to say "net force" is "resultant force".

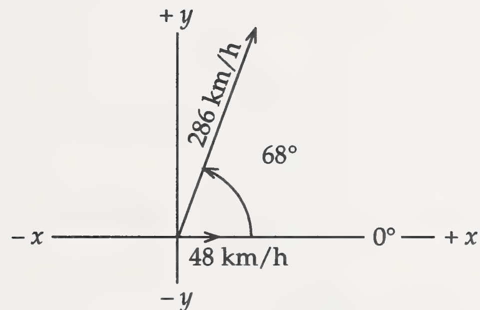
   b. Another way to say "horizontal component" is "x-component".

   c. This sum is called the net x-component ($F_{net\ x}$).

   d. This sum is called the net y-component ($F_{net\ y}$).

   e. The Pythagorean theorem is used.

6. 



- Resolve the 286 km/h vector.

$$v_x = 286(\cos 68°)$$
$$= 107.1 \text{ km/h}$$
$$v_y = 286(\sin 68°)$$
$$= 265.2 \text{ km/h}$$

- Resolve the 48 km/h vector.

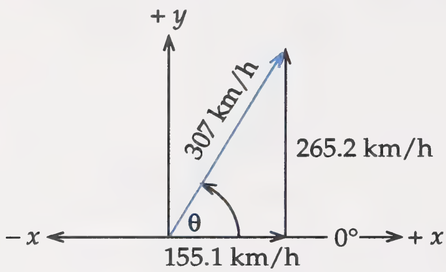
$$v_x = 48 \text{ km/h}$$
$$v_y = 0$$

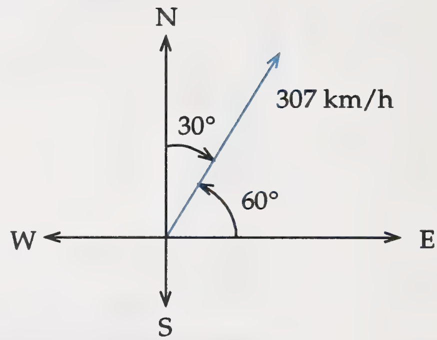
- Find the magnitude of the resultant.

$$v_{net\ x} = 107.1 \text{ km/h} + 48 \text{ km/h}$$
$$= 155.1 \text{ km/h}$$
$$v_{net\ y} = 265.2 \text{ km/h} + 0$$
$$= 265.2 \text{ km/h}$$

$$C^2 = A^2 + B^2$$
$$C^2 = \left(v_{net\ x}\right)^2 + \left(v_{net\ y}\right)^2$$
$$C^2 = (155.1\ \text{km/h})^2 + (265.2\ \text{km/h})^2$$
$$C = 307\ \text{km/h}$$

- Calculate the angle.

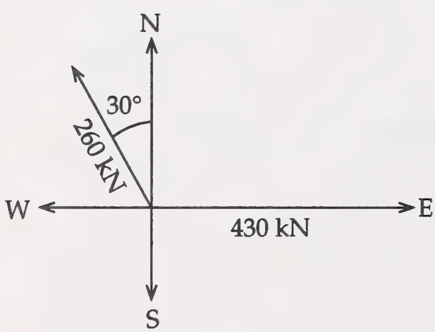


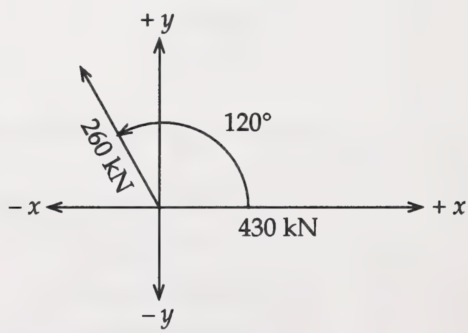


$$\tan\ \theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{265.2\ \text{km/h}}{155.1\ \text{km/h}}$$
$$\theta = 59.7°$$
$$= 60°$$

The plane moves at 307 km/h, N30°E. Note that the direction could also be given as E60°N.

7.





- Resolve the 430 kN vector.

$$F_x = 430\ \text{kN}$$
$$F_y = 0$$

- Resolve the 260 kN vector.

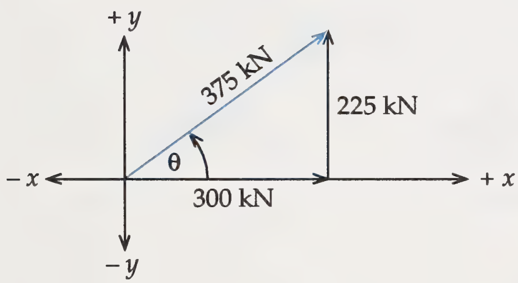
$$F_x = 260\text{ kN}(\cos 120°)$$
$$= -130\text{ kN}$$
$$F_y = 260\text{ kN}(\sin 120°)$$
$$= 225\text{ kN}$$

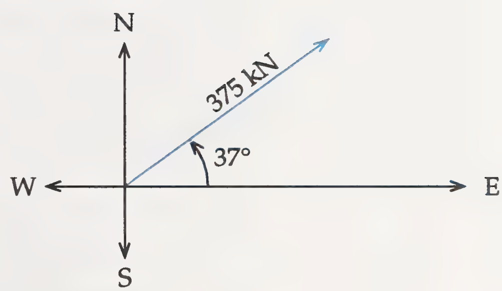
- Find the magnitude of the resultant.

$$F_{net\,x} = -130\text{ kN} + 430\text{ kN}$$
$$= 300\text{ kN}$$
$$F_{net\,y} = 225\text{ kN} + 0$$

$$C^2 = A^2 + B^2$$
$$C^2 = (F_{net\,y})^2 + (F_{net\,x})^2$$
$$C^2 = (225\text{ kN})^2 + (300\text{ kN})^2$$
$$C = 375\text{ kN}$$

- Calculate the angle.

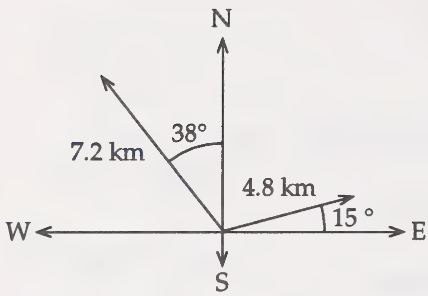


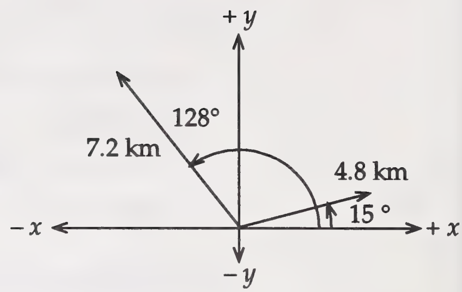


$$\tan\ \theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{225\text{ kN}}{300\text{ kN}}$$
$$\theta = 37°$$

The tugboats pull with a resultant force of 375 kN, E 37°N.

8.





- Resolve the 4.8 km vector.

$$\begin{aligned} d_x &= 4.8\text{ km}(\cos 15°) \\ &= 4.64\text{ km} \\ d_y &= 4.8\text{ km}(\sin 15°) \\ &= 1.24\text{ km} \end{aligned}$$

- Resolve the 7.2 km vector.

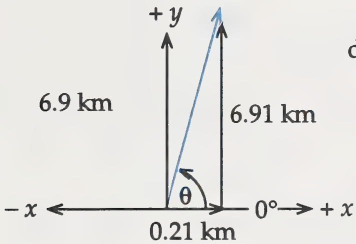
$$\begin{aligned} d_x &= 7.2\text{ km}(\cos 128°) \\ &= -4.43\text{ km} \\ d_y &= 7.2\text{ km}(\sin 128°) \\ &= 5.67\text{ km} \end{aligned}$$

- Find the magnitude of the resultant.

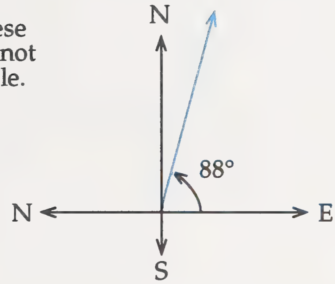
$$\begin{aligned} d_{net\ x} &= 4.64\text{ km} + (-4.43\text{ km}) \\ &= 0.21\text{ km} \\ d_{net\ y} &= 1.24\text{ km} + 5.67\text{ km} \\ &= 6.91\text{ km} \end{aligned}$$

$$\begin{aligned} C^2 &= A^2 + B^2 \\ C^2 &= (d_{net\ x})^2 + (d_{net\ y})^2 \\ C^2 &= (0.21\text{ km})^2 + (6.91\text{ km})^2 \\ C &= 6.913\text{ km} \\ C &= 6.9\text{ km} \end{aligned}$$

• Calculate the angle.



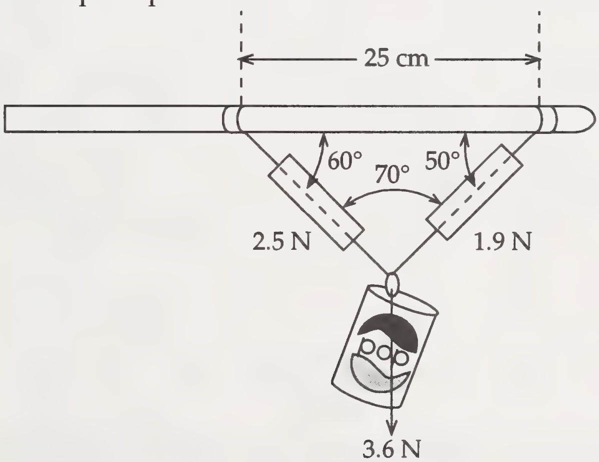
Note that these diagrams are not drawn to scale.



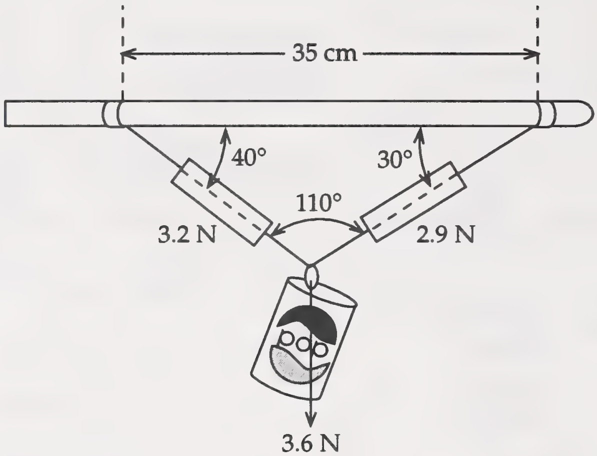
$$\tan\ \theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{6.91\text{ km}}{0.21\text{ km}}$$
$$\theta = 88°$$

The hiker's net displacement is 6.9 km, E88°N. Note that the direction could also be given as N2°E.

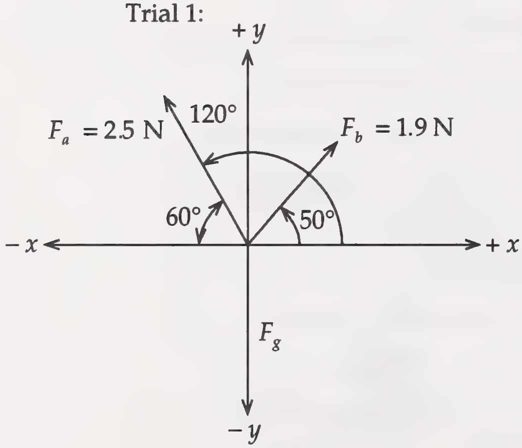
9. Trial 1: This is a sample of possible results.

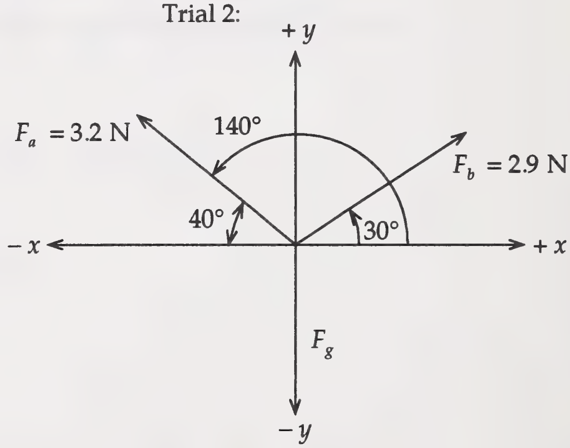


10. Trial 2: This is a sample of possible results.



11. Since the long stick was horizontal, the angles to the x-axis can be found using alternate interior angles. The weight of the can is assumed to be directed downwards along the y-axis.





12. Trial 1: These calculations are for the sample data provided.

- Resolve the 2.5 N vector.

$$F_x = 2.5\ \text{N}(\cos 120°)$$
$$= -1.25\ \text{N}$$

$$F_y = 2.5\ \text{N}(\sin 120°)$$
$$= 2.17\ \text{N}$$

- Resolve the 1.9 N vector.

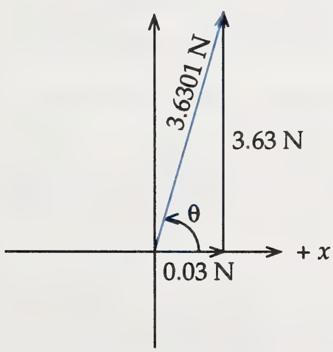
$$F_x = 1.9\text{ N}(\cos 50°)$$
$$= 1.22\text{ N}$$
$$F_y = 1.9\text{ N}(\sin 50°)$$
$$= 1.46\text{ N}$$

- Find the magnitude of the resultant.

$$F_{net\ x} = -1.25\text{ N} + 1.22\text{ N}$$
$$= -0.03\text{ N}$$
$$F_{net\ y} = 2.17\text{ N} + 1.46\text{ N}$$
$$= 3.63\text{ N}$$

$$C^2 = A^2 + B^2$$
$$C^2 = (F_{net\ x})^2 + (F_{net\ y})^2$$
$$C^2 = (-0.03\text{ N})^2 + (3.63\text{ N})^2$$
$$C = 3.6301\text{ N}$$
$$C = 3.6\text{ N}$$

- Find the angle.



This diagram is not drawn to scale.

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{3.63\ N}{0.03\ N}$$
$$= 89.5°$$
$$= 90°$$

The resultant force is 3.6 N directed 90° up from the horizontal. This direction could also be described as being vertical, or opposite the force of gravity.

13. Trial 2: These calculations are for the sample data provided.

- Resolve the 3.2 N vector.

$$
\begin{aligned}
F_x &= 3.2\ \text{N}(\cos 140°) \\
&= -2.45\ \text{N} \\
F_y &= 3.2\ \text{N}(\sin 140°) \\
&= 2.06\ \text{N}
\end{aligned}
$$

- Resolve the 2.9 N vector.

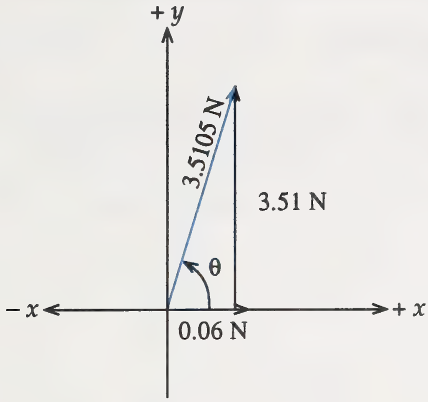
$$
\begin{aligned}
F_x &= 2.9\ \text{N}(\cos 30°) \\
&= 2.51\ \text{N} \\
F_y &= 2.9\ \text{N}(\sin 30°) \\
&= 1.45\ \text{N}
\end{aligned}
$$

- Find the magnitude of the resultant.

$$
\begin{aligned}
F_{net\ x} &= -2.45\ \text{N} + 2.51\ \text{N} \\
&= 0.06\ \text{N} \\
F_{net\ y} &= 2.06\ \text{N} + 1.45\ \text{N} \\
&= 3.51\ \text{N}
\end{aligned}
$$

$$
\begin{aligned}
C^2 &= A^2 + B^2 \\
C^2 &= (F_{net\ x})^2 + (F_{net\ y})^2 \\
C^2 &= (0.06\ \text{N})^2 + (3.51\ \text{N})^2 \\
C &= 3.5105\ \text{N}
\end{aligned}
$$

- Find the angle.



This diagram is not to scale.

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{3.51\ \text{N}}{0.06\ \text{N}}$$
$$\theta = 89.0^\circ$$
$$= 89^\circ$$

The resultant force is 3.5 N directed 89° up from the horizontal. This direction could also be described as being almost vertical, or opposite the force of gravity.

14. The resultant for both trials is very close to 3.6 N almost straight up. This is almost equal and opposite to the weight, which is 3.6 N down.

15. The spring scale readings were higher when the scales were moved further apart.

16. David could ease the tension in the line by using more line and dropping the weight lower, but not so low that the bears can reach the food.

17. Forces are in equilibrium when the vector sum of all the forces is zero.

18. The equilibrant is the force that will produce equilibrium when applied to the other forces. It is equal and opposite to the resultant of the other forces.

19. Answers to these problems can be found on pages 665 and 666 of your textbook.

20. The following list represents the most important equations that were introduced for the first time in this module. Pay close attention to the use of vector notation.

Module 2: Explaining How Things Move

- General Equations:

$$\vec{p} = m\vec{v}$$

$$F_f = \mu F_n$$

- Newton's Second Law:

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{F}_g = m\vec{g}$$

$$\vec{F}\Delta t = m\Delta\vec{v}$$

- Newton's Third Law:

$$\vec{F}_{1\to2} = -\vec{F}_{2\to1}$$

$$\Delta\vec{p}_1 = -\Delta\vec{p}_2$$

$$\vec{F}_{1\to2}\Delta t = -\vec{F}_{2\to1}\Delta t$$

- Useful Mathematical Equations: (These should be memorized.)

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$C^2 = A^2 + B^2$$

- Other Mathematical Equations:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \qquad c^2 = a^2 + b^2 - 2ab\cos C$$

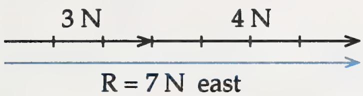
Section 3: Follow-up Activities

Extra Help

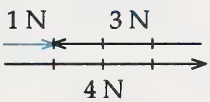
1. Scalars are quantities with only a magnitude, whereas vector quantities have magnitude and direction. Vectors are added by placing the head of the first to the tail of the next.

2. Four examples of vectors are displacement, velocity, acceleration, and force.

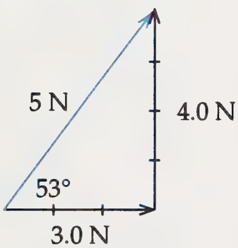
3. a.



b.



c.

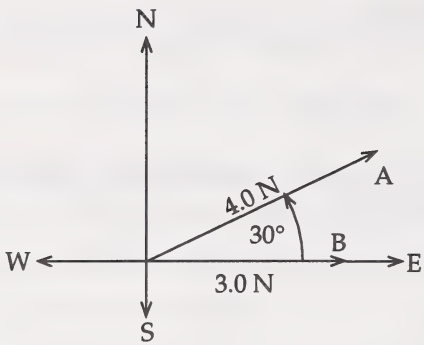


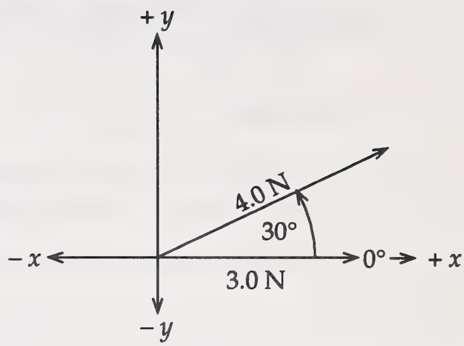
$$C^2 = A^2 + B^2$$
$$C^2 = 3.0^2 + 4.0^2$$
$$C = 5.0\ \text{N}$$

$$\tan\,\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{4.0\ \text{N}}{3.0\ \text{N}}$$
$$\theta = 53°$$

The resultant is 5.0 N, N37°E. The direction could also be given as E53°N.

d.





- Resolve the 4.0 N vector.

$$F_x = 4.0\text{ N}(\cos 30°)$$
$$= 3.46\text{ N}$$
$$F_y = 4.0\text{ N}(\sin 30°)$$
$$= 2.0\text{ N}$$

- Resolve the 3.0 N vector.

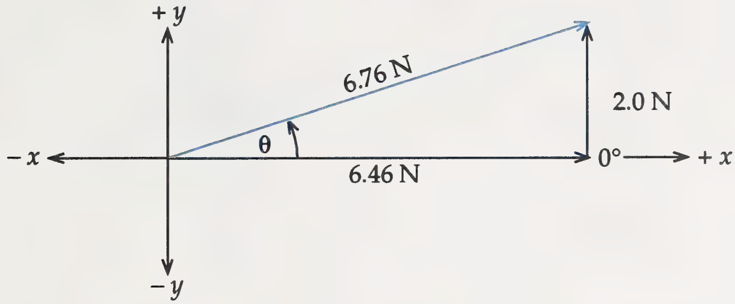
$$F_x = 3.0\text{ N}$$
$$F_y = 0\text{ N}$$

- Find the magnitude of the resultant.

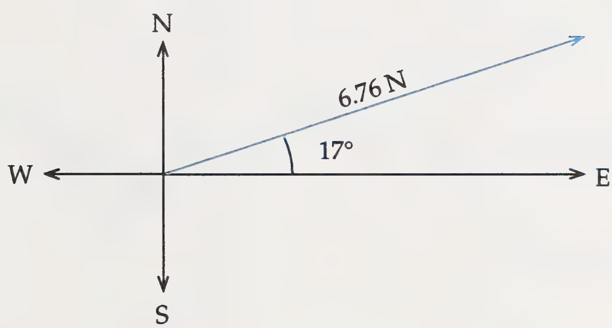
$$F_{net\ x} = 3.46\text{ N} + 3.0\text{ N}$$
$$= 6.46\text{ N}$$
$$F_{net\ y} = 2.0\text{ N} + 0$$
$$= 2.0\text{ N}$$

$$C^2 = A^2 + B^2$$
$$C^2 = (6.46\text{ N})^2 + (2.0\text{ N})^2$$
$$C = 6.76\text{ N}$$

- Find the angle.

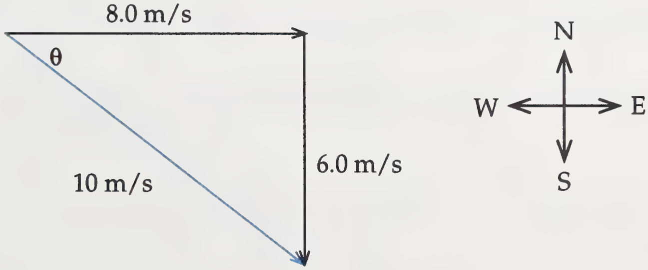


$$\tan \theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{2.0\text{ N}}{6.46\text{ N}}$$
$$\theta = 17.2°$$
$$= 17°$$



The resultant is 6.8 N, E17°N. The direction could also be given as N73°E.

4. a.



$$C^2 = A^2 + B^2$$
$$C^2 = (8.0\text{ m/s})^2 + (6.0\text{ m/s})^2$$
$$C = 10\text{ m/s}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{6.0\text{ m/s}}{8.0\text{ m/s}}$$
$$\theta = 37°$$

The resultant velocity is 10 m/s, E37°S.

b. $v = \dfrac{d}{t}$

$$t = \frac{d}{v}$$
$$= \frac{100\text{ m}}{6.0\text{ m/s}}$$
$$= 16.7\text{ s}$$
$$= 17\text{ s}$$

It takes David 17 s to cross the river.

c. $d = vt$

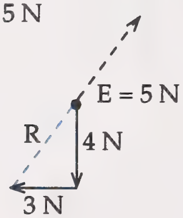
$$= (8.0\text{ m/s})(16.7\text{ s})$$
$$= 134\text{ m}$$

David will dock 1.3×10^2 m downstream.

5. a. 7 N

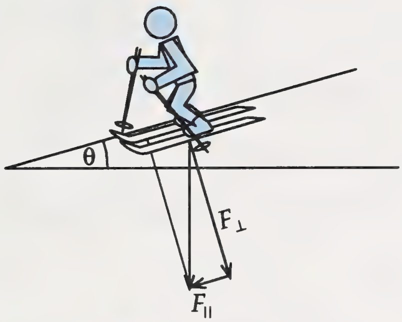
b. 5 N

c. 5 N

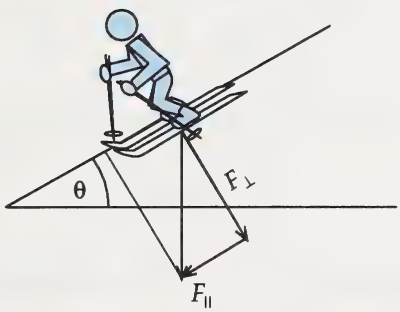


Enrichment

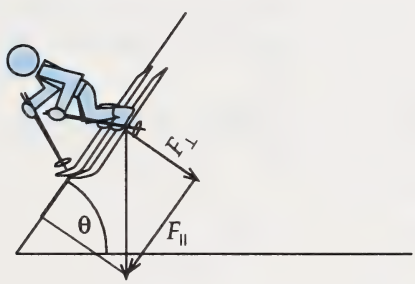
1. a.



b.



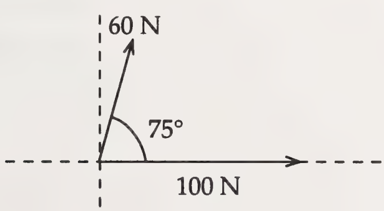
c.



d. The parallel and perpendicular components will be equal at 45°.

e. The parallel component reaches a maximum at 90° and a minimum at 0°.

2. a. Rotate the 100-N vector down to the x-axis. Rotate the 60-N vector so that there is still 75° between the two. Then solve.



- Resolve the 100-N vector into its components.

$$F_x = 100\text{ N} \qquad F_y = 0$$

- Resolve the 60-N vector into its components.

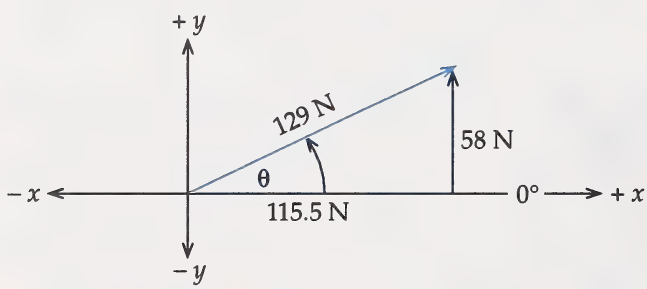
$$\begin{aligned} F_x &= 60\text{ N}(\cos 75°) \\ &= 15.5\text{ N} \end{aligned} \qquad \begin{aligned} F_y &= 60\text{ N}(\sin 75°) \\ &= 58\text{ N} \end{aligned}$$

- Find the net x- and y-components.

$$\begin{aligned} F_{net\ x} &= 100\text{ N} + 15.5\text{ N} \\ &= 115.5\text{ N} \end{aligned} \qquad \begin{aligned} F_{net\ y} &= 0 + 58\text{ N} \\ &= 58\text{ N} \end{aligned}$$

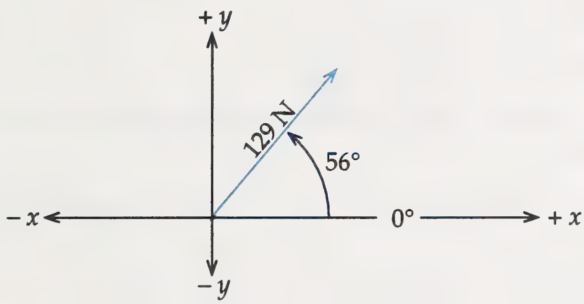
- Use the Pythagorean theorem to find the resultant.

$$\begin{aligned} A^2 + B^2 &= C^2 \\ (115.5\text{ N})^2 + (58\text{ N})^2 &= C^2 \\ C &= 129\text{ N} \end{aligned}$$



$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{58\text{ N}}{115.5\text{ N}}$$
$$\theta = 26.6°$$

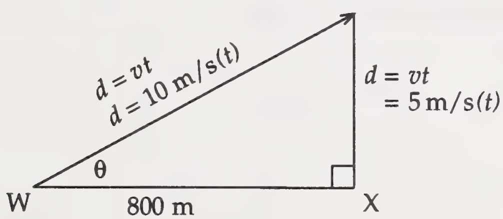
- Now rotate this angle back 30° in the counterclockwise direction.



The final answer is 1.3×10^2 N, directed at 56°.

b. The technique of vector rotation saves time by reducing the need for trigonometry when resolving one of the vectors into its components. This also makes calculations easier.

3. a. • Calculate the time it takes to get from Ship W to Ship X.



$$A^2 + B^2 = C^2$$
$$(800\text{ m})^2 + (5\text{ m/s}\bullet t)^2 = (10\text{ m/s}\bullet t)^2$$
$$640\,000 + 25t^2 = 100t^2$$
$$640\,000 = 75t^2$$
$$t = 92.4\text{ s}$$

- Calculate the time it takes to get from Ship X to Ship Y.

  The small boat moves toward Ship Y at 10 m/s and Ship Y moves towards the boat at 5 m/s, so the net speed toward Ship Y is 15 m/s.

$$v = \frac{d}{t}$$
$$t = \frac{d}{v}$$
$$= \frac{800\text{ m}}{15\text{ m/s}}$$
$$t = 53.3\text{ s}$$

- The time to get from Ship Y to Ship Z is the same as it was to get from Ship W to Ship X (92.4 s).

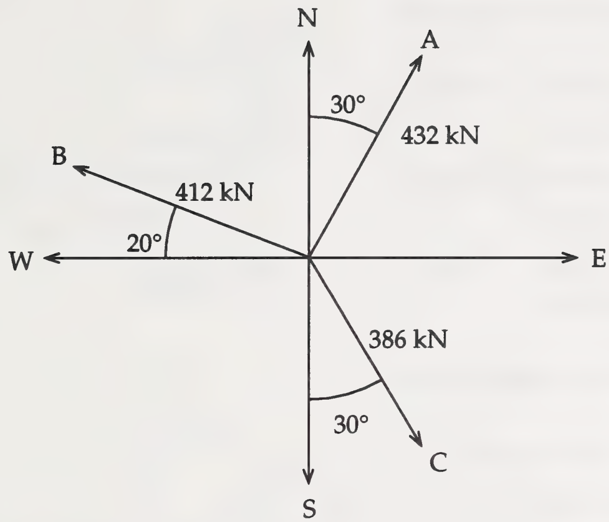
- Calculate the time from Ship Z to Ship W. The net speed toward Ship W is 5 m/s.

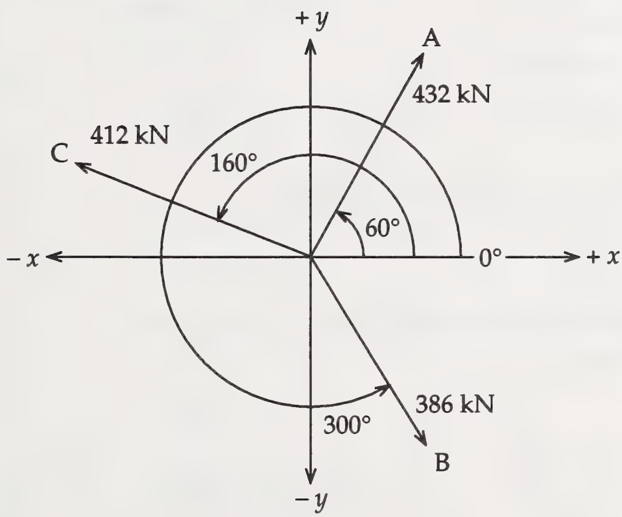
$$v = \frac{d}{t}$$
$$t = \frac{d}{v}$$
$$= \frac{800\text{ m}}{5\text{ m/s}}$$
$$t = 160\text{ s}$$

- Calculate the total time for the round trip.

$$\begin{aligned} t_{net} &= 92.4\text{ s} + 53.3\text{ s} + 92.4\text{ s} + 160\text{ s} \\ &= 398.1\text{ s} \\ &= 6.6\text{ min} \end{aligned}$$

b.


N
A
30°
432 kN
B
412 kN
20°
W
E
386 kN
30°
C
S


+ y
A
432 kN
412 kN
C
160°
60°
− x
0°
+ x
386 kN
300°
B
− y

- Calculate the x-components.

$$\begin{aligned} F_{a_x} &= (432\text{ kN})(\cos 60°) \\ &= 216\text{ kN} \\ F_{b_x} &= (412\text{ kN})(\cos 160°) \\ &= -387\text{ kN} \\ F_{c_x} &= (386\text{ kN})(\cos 300°) \\ &= 193\text{ kN} \end{aligned}$$

$$\begin{aligned} F_{net\ x} &= 216\text{ kN} + (-387\text{ kN}) + 193\text{ kN} \\ &= 22\text{ kN} \end{aligned}$$

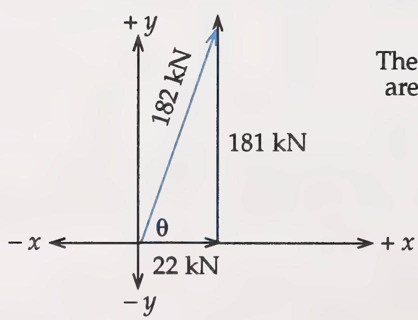
- Calculate the y-components.

$$\begin{aligned} F_{a_y} &= 432\text{ kN}(\sin 60°) \\ &= 374\text{ kN} \\ F_{b_y} &= 412\text{ kN}(\sin 160°) \\ &= 141\text{ kN} \\ F_{c_y} &= 386\text{ kN}(\sin 300°) \\ &= -334\text{ kN} \end{aligned}$$

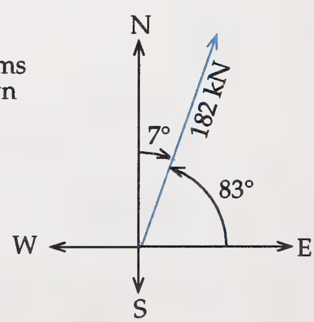
$$\begin{aligned} F_{net\ y} &= 374 + 141 + (-334) \\ &= 181\text{ kN} \end{aligned}$$

- Calculate the magnitude of the resultant.

$$\begin{aligned} C^2 &= A^2 + B^2 \\ C^2 &= (22\text{ kN})^2 + (181\text{ kN})^2 \\ C &= 182\text{ kN} \end{aligned}$$



These diagrams are not drawn to scale.



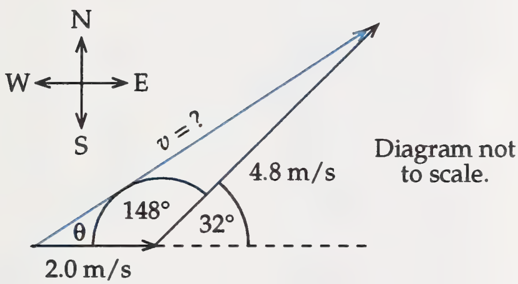
$$\tan \theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\tan \theta = \frac{181 \text{ kN}}{22 \text{ kN}}$$

$$\theta = 83°$$

The net force on the barge is 182 kN, N7°E. The direction could also be given as E83°N.

c.



- Use the law of cosines to calculate the resultant.

$$c^2 = a^2 + b^2 - 2ab \cos C$$

$$c^2 = (2.0 \text{ m/s})^2 + (4.8 \text{ m/s})^2 - 2(2.0 \text{ m/s})(4.8 \text{ m/s})(\cos 148°)$$

$$c = 6.6 \text{ m/s}$$

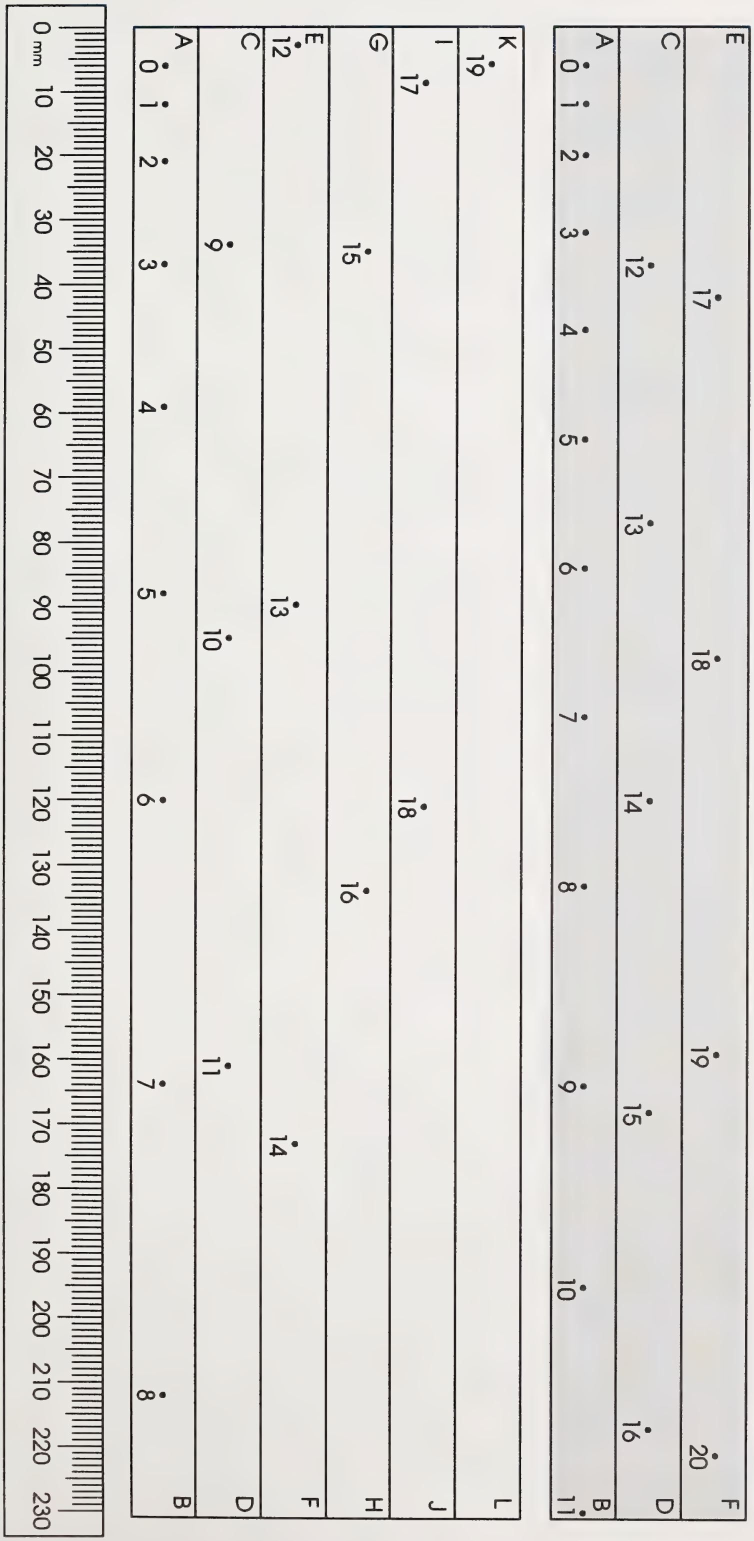
- Now use the law of sines to calculate the angle.

$$\frac{a}{\sin A} = \frac{b}{\sin B}$$

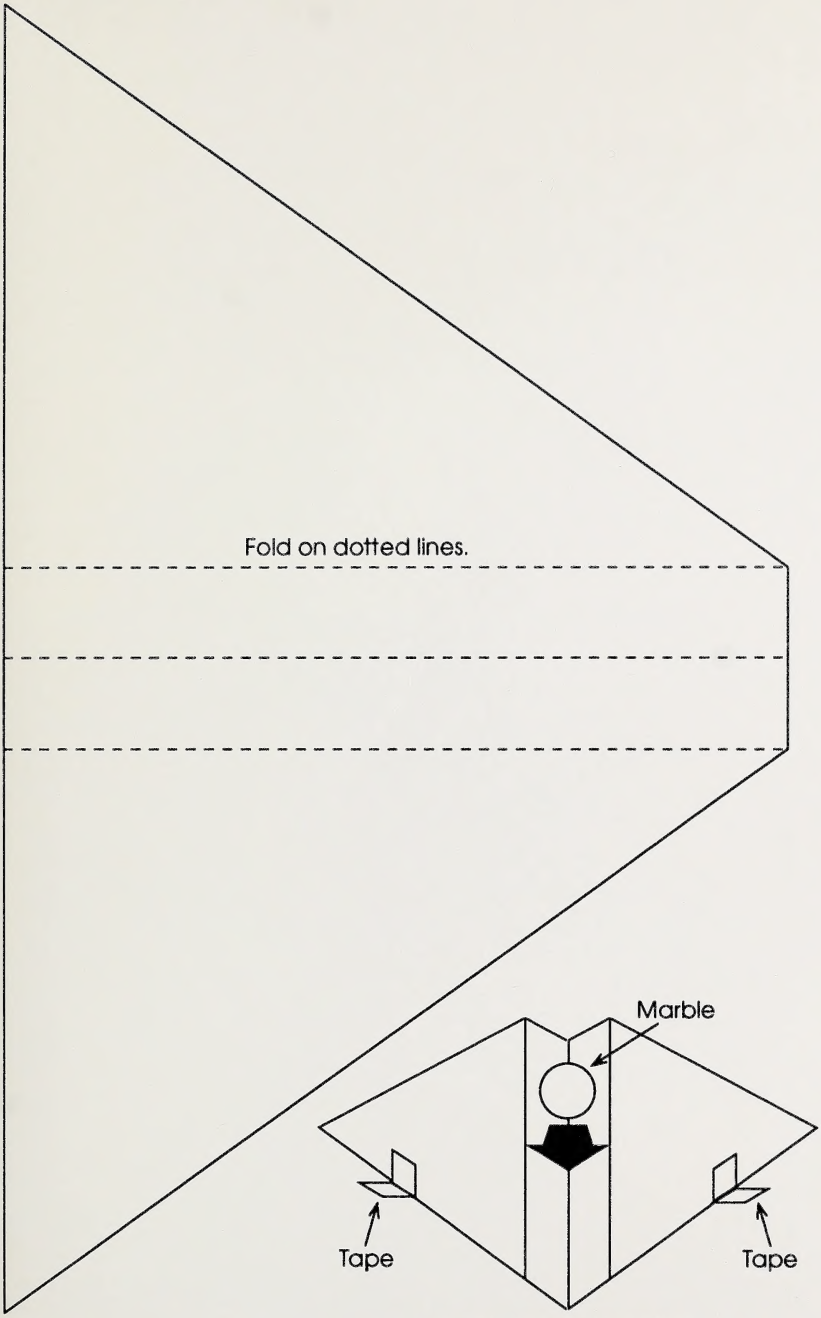
$$\frac{6.6 \text{ m/s}}{\sin 148°} = \frac{4.8 \text{ m/s}}{\sin \theta}$$

$$\theta = 22.7°$$

The resultant velocity of the boat is 6.6 m/s, E23°N.



E 17 18 19 20 F
C 12 13 14 15 16 D
A 0 1 2 3 4 5 6 7 8 9 10 11 B
K 19 L
I 17 18 J
G 15 16 H
E 12 13 14 F
C 9 10 11 D
A 0 1 2 3 4 5 6 7 8 B
0 mm 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230



Front view of launcher

Physics 20

Student Module Booklet
Module 2

L.R.D.C.
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